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FULL PAPERS

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Contents

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Theme 1. The Digital Revolution

Revolutionizing higher education: A technical review of artificial intelligence integration

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Abstract:
Artificial intelligence (AI) storms through, making qualitative breakthroughs in performance and production in all life fields, including higher education. This study presents a comprehensive investigation of diverse dimensions of AI technologies employed in the realm of higher education to outperform current learning outcomes, aiming to utilize automation, optimization, and data-driven decision insights functions offered by AI. A systematic approach is adopted by reviewing the current literature and analyzing the latest case studies to build solid AI architecture by identifying the diverse array of where AI technologies are used in the higher education sector. The study investigates adaptive learning systems, intelligent tutoring systems, virtual assistants, learning analytics, natural language processing (NLP), virtual reality (VL), augmented reality (AR), plagiarism detection tools, automated grading systems, and personalized recommender systems. The results demonstrate the transformative role of AI in restructuring higher education, where AI enhances dramatically pedagogical practices, personalizes learning experiences, improves student engagement and retention, optimizes administrative workflow, and fosters a dynamic educational environment. This study provides the stakeholders in the higher education sector with insight into the AI technologies and architectures that should be adopted to attain a competitive edge and enhance learning outcomes.

I. Introduction:

Digital development in the 21st century is driven by artificial intelligence (AI). This technological tool is revolutionizing many industries including higher education by enabling machines to mimic human behavior (Bates et al., 2020; Zhai et al., 2021; Chen et al., 2020; Ahmad et al., 2021). Among the most important human behaviors that can be simulated by AI are pattern recognition, language understanding, learning, adaptation, problem-solving, decision-making, and finally perception (Chen et al., 2020; Hwang et al., 2020; Ouyang & Jiao, 2021; Khosravi et al., 2022). Simulating human behavior with high efficiency enables people to enhance productivity, improve the decision-making process, and push for innovation and creativity in all fields, the most important of which is education (Yang et al., 2021; Guan et al., 2020; Zhang & Aslan, 2021; Kumar et al., 2023; Kabudi et al., 2021).

The realm of AI includes many technologies, but there are basic and pivotal technologies that will be discussed and defined for the reader to facilitate understanding of the rest of the technical concepts that will be called through this paper, which are machine learning (ML), natural language processing (NLP), and data analytics. By understanding the basic technologies of AI in higher education, readers gain a comprehensive understanding of how AI can advance the reality of higher education and promote positive teaching and learning practices that in turn contribute to a smooth transition. In higher education, these technologies contribute directly or indirectly to customizing educational experiences for students to meet the individual needs and preferences. In addition, they enhance and evaluate teaching and learning, enhance institutional efficiency, and play a major role in advancing the field of development and innovation. The technologies are:

Machine learning (ML) algorithms: ML is an important branch of AI, where algorithms are developed that enable computers to learn, predict, and make decisions based on the data that is fed to them and the goals for which the model is designed (Luan & Tsai, 2021; Kuleto et al., 2021; Yağcı, 2022). In general, ML contributes effectively to the world of higher education (Luan & Tsai, 2021). This branch contributes to many important and basic applications that help in identifying patterns, prediction, customization, automation, optimization, anomaly detection, autonomous systems, continuous learning, and adaptation (Kuleto et al., 2021). In higher education, ML is used to predict student success and personalized educational experiences and design content delivery to individual students' needs (Yağcı, 2022).

Natural Language Processing (NLP): The second crucial branch in the AI realm is NLP. To mimic human behavior the machine needs to interact with human languages. The NLP algorithm is used to understand, interpret, and generate text or speech (Fuchs, 2023; Alqahtani et al., 2023). This revolutionizes education in different ways. Nowadays, students can have virtual assistance, chatbots, and language translation tools, and many AI tools help with the education process (Fuchs, 2023). NLP contributes by enabling natural language interfaces that facilitate interactive learning environments (Alqahtani et al., 2023).

Data Analytics: This is also one of the most important branches of AI. AI-involved data analytics include collecting, analyzing, interpreting, and visualizing data to extract valuable insights that can support decision-making in AI systems. By utilizing AI techniques in data analytics, the patterns, trends, correlations, and any other meaningful information are extracted to be harnessed and improve the overall system performance (Nguyen et al., 2020; Ashaari et al., 2021; Sekli & De La Vega, 2021). In education, data analytics process the educational data to give an insight into student performance, engagement, and learning patterns (Nguyen et al., 2020; Ashaari et al., 2021). This technique leads to a continuation of updating and learning in the education system for the benefit of the students (Sekli & De La Vega, 2021).

Overall, the integration of AI technologies in higher education promises improved efficiency, tailored support mechanisms, and dynamic learning environments, fostering enhanced academic experiences for students and educators alike. Considering the vital role of higher education for the community, the incorporation of AI tools in this sector becomes crucial to keep pace with the paradigm shift. It significantly contributes to enhancing teaching effectiveness, improving learning experiences, supporting students' success, and driving innovation and research. To take advantage of AI", the stakeholders need a thorough comprehension of AI system architecture in the educational environment to build a clear vision and effectively implement strategies for its integration and utilization. Thus, this study conducts a systematic literature review of the last four years (2020 – 2024). Based on the literature review conducted in this work, the literature shows that there is a lack of comprehensive understanding of AI-based architecture in higher education. Therefore, this paper builds a clear vision of a holistic AI systems architecture in higher education.

The remainder of this paper is structured as follows: Section II discusses the research gap and methodology, Section III presents the overview of the literature review, Section IV details the results obtained from the search process by introducing the holistic architecture of AI-based systems in higher Education, Section V deliberates on the challenges and limitations of AI-based systems in higher education, and Section VI concludes the study with suggested future works.

II. Research Gap and Methodology

In this section, the research gap is defined, and the research methodology is clarified. The research gap is the lack of a recent study investigating AI technical systems in higher education, as will be explained in the literature reviews section and based on our investigation the holistic vision of the AI-based higher education architecture will be drawn. Initially, a systematic literature review study is conducted to explore different technical AI systems in higher education, focusing on the well-known library, Google Scholar. Google Scholar is widely used, and it is an open-source academic search engine that provides access to a variety of scholarly literature, including journal articles, conference papers, and dissertations. This engine provides many features to filter recently published references and those with a high citation index, along with indicating the source in which they were published. Google Scholar was chosen as the primary resource for several factors:

1. Google Scholar indexes a wide range of academic publications from various disciplines. It provided us with comprehensive coverage of research related to AI in higher education.
2. Google Scholar's search algorithms prioritize reputable and frequently cited sources. This ensures relevant and reliable literature is included.
3. The filtering feature can be used to select recently published publications which were from 2020 to 2024. This enables us to monitor the latest developments and trends in AI in higher education.

The search strategy involves using specific keywords related to AI and higher education, such as “Artificial Intelligence (AI)”, “Higher Education”, “Machine Learning (ML)”, “Natural Language Processing (NLP)”, “Data Analytics”, “Deep Learning”, “Intelligent teaching systems”, and “Educational technology”. These keywords are systematically combined and used to query Google Scholar, resulting in a comprehensive collection of relevant publications. To ensure the inclusion of high-quality, influential research, search results are filtered based on citation metrics, such as the number of citations. Highly cited publications are prioritized, as they indicate scientific importance and influence within the academic community. In addition, preference was given to publications from reputable journals and conferences, which undergo rigorous peer review processes to ensure methodological rigor and academic rigor. Inclusion criteria for selected publications include relevance to the research topic, date of publication within the selected period (2020-2024), and availability of full-text access. Studies that meet these criteria are included in the review, while those that do not meet these criteria are excluded. Data extraction involves retrieving basic information from the selected publications, including authors, year of publication, title, abstract, and main findings. This information is collected and analyzed to define AI systems in higher education and draw a clear vision of the structure of the modern educational system based on AI. Overall, the systematic literature review methodology adopted in this study ensures a comprehensive definition of current AI systems in higher education, taking advantage of the rich resources available from Google Scholar. By focusing on recent and highly cited publications, this study aims to provide valuable insights and contribute to the advancement of knowledge in this field.

III. Literature Review

In this important part of the study, a systematic review of the literature for the last four years is conducted to define the main systems and technologies of AI in higher education. The keywords defined in the previous section were used for search in Google Scholar. The following groups of literature are found. The first group of literature: Bates et al., 2020; Zhai et al., 2021; Hemachandran et al. al., 2022, focused on AI-based technologies, where they ensure that AI technologies are revolutionizing the educational landscape by providing personalized learning experiences, facilitating learner-teacher interaction, and predicting academic success by using different systems such as intelligent tutoring systems, virtual learning assistants, and personalized learning. The second group of literature (Chen et al., 2020; King & ChatGPT, 2023; Ahmad et al., 2021; Luan et al., 2020) verified that AI-based platforms provide insights into student performance and behavior, support adaptive learning styles, and enable the detection of academic misconduct, such as plagiarism. The third group (Alyahyan & Düştegör, 2020; Seo et al., 2021; Okonkwo & Ade-Ibijola, 2021; Dempere et al., 2023; Zhang & Aslan, 2021; Kumar et al., 2023) confirm that the ongoing research and innovation in the field of AI are reshaping higher education, providing new opportunities for learning, collaboration, and engagement. Also, many sources address the ethical aspects of adopting AI in higher education as Yang et al., 2021; Guan et al., 2020; and Rudolph et al., 2023. This amazing development faces great challenges, as ethical considerations must be considered, and the decisions made by AI need to be explained, and therefore there is a need to design systems that can be interpreted and understood in a transparent and simplified way for users.

The literature has been reviewed. They cover various aspects but none of them provide a comprehensive view of AI-based architecture in higher education. However, the content in the literature leads us to define more keywords such as “Intelligent Tutoring”, “Personalized Learning”, “Virtual Learning”, “Predictive Analytics”, “Adaptive

Assessment", and "Content Recommendation". Thus, literature research is zoomed in to examine different AI-based systems in higher education by using more sophisticated keywords and classifying the literature into themes.

Themes Definition:

The classifications are presented in six themes. For accuracy and practical purposes, each theme concluded from the five most recent and highly cited pieces of literature in "Google Scholer". The six themes are presented as follows:

Theme 1:

This theme introduces the intelligent tutoring system as one of the important systems in modern higher education. The following recent publications shed light on various aspects of intelligent tutoring systems: (Alam, 2023; Mousavinasab et al., 2021; Conati et al., 2021; Guo et al., 2021; St-Hilaire et al., 2022; Eryılmaz & Adabashi, 2020). These references explore this system in different ways. Alam (2023) explored the use of AI to develop intelligent tutoring systems aimed at enhancing classroom experiences and improving learning outcomes. Also, Mousavinasab et al. (2021) conducted a systematic review to identify the characteristics, applications, and evaluation methods of intelligent tutoring systems. Furthermore, Conati et al. (2021) investigated personal explainable AI (XAI) through a case study in intelligent tutoring systems. In addition, Guo et al. (2021) provided an interdisciplinary and scientific perspective on the development and trends in research on intelligent tutoring systems. St-Hilaire et al. (2022) discussed the transformative potential of intelligent tutoring systems in online learning environments. Eryılmaz and Adabashi (2020) developed an intelligent tutoring system that uses virtual networks and fuzzy logic to enhance students' academic performance.

Theme 2:

Furthermore, in this theme, the personal learning platform is introduced as a second important system of AI-based architecture in higher education. The following recent publications offer insights into different dimensions of personal learning platforms: (Tapalova & Zhiyenbayeva, 2022; Bhutoria, 2022; Whalley et al., 2021; Alamri et al., 2020; Rane et al., 2023; Essa et al., 2023; Chang et al., 2023). Tapalova and Zhiyenbayeva (2022) examined AI in education specifically in the context of personalized learning pathways. In addition, Bhutoria (2022) conducted a systematic review exploring personalized learning and AI in different countries. Also, Whalley et al. (2021) investigated the effects of AI on flexible personalized learning in the wake of the COVID-19 pandemic. Alamri et al. (2020)

explored the use of personalized learning to motivate learners in online higher education. Rane and Choudhary (2023) discussed integrating AI for personalized and adaptive learning into Education 4.0 and 5.0 frameworks. Essa, Celik, and Human-Hendricks (2023) conducted a systematic review of the literature on personalized adaptive learning techniques based on ML techniques. In addition, Chang et al. (2023) examined instructional design principles for AI-enabled chatbots that support self-regulated learning in education.

Theme 3:

Moreover, this theme presented the virtual learning system as part of the architecture. The following recent publications provide perspectives on various facets of virtual learning system: (Wang et al., 2023; Rudolph et al., 2023; Hannan & Liu, 2023; Mohd Rahim et al., 2022; Dempere et al., 2023). Wang et al. (2023) investigated the potential impacts of AI on international students in higher education. The authors focused on generative AI, chatbots, and analytics and their impact on international student success. Also, the work of Rudolph et al. (2023) addressed the competitive landscape of chatbots in higher education, examining platforms such as Bard, Bing Chat, ChatGPT, and Ernie, and examining their role in the evolving AI-driven educational environment. Meanwhile, Hannan and Liu (2023) highlighted the emergence of AI as a new source of competitiveness in higher education and discussed its multifaceted applications and implications. In addition, Muhammad Rahim et al. (2022) presented an innovative AI-based chatbot adoption model designed for higher education institutions. They used a hybrid PLS-SEM neural network modeling approach. Finally, Dempere et al. (2023) explored the specific impact of ChatGPT on higher education, providing insights into its impacts and impacts within the educational sector.

Theme 4:

In the fourth theme, the predictive analytics system is unveiled as one of the main systems of holistic AI-based architecture. The following recent publications delve into the intricacies of predictive analytics systems: (Doleck et al., 2020; Luan et al., 2020; Gao et al., 2021; Fischer et al., 2020; Teng et al., 2023; Umer et al., 2023). A comparative analysis of ML frameworks specifically deep learning for predictive analytics was conducted in (Doleck et al. 2020), where the authors highlighted the diverse approaches and methodologies used in higher education. The authors Gao et al. (2021) presented key technologies in AI, e-learning, and big data-based e-learning, focusing on the impact of AI technology on advancing higher education outcomes. Given the importance of data, especially big data, for ML and deep learning of this system, Fischer et al. (2020) explored the potential and challenges of big data mining in education, highlighting the need for ethical and responsible data practices to harness the full potential of these technologies. Also, Luan et al. (2020) discussed the challenges and future trends of big data in AI-based education and highlighted the complexities and opportunities inherent in leveraging large-scale data analytics to improve education. Designing educational models that help in the decision-making process was one of the ideas and works of Teng et al. (2023). The authors proposed a data- and AI-driven decision-making model for higher education systems, providing insights into the application of AI in improving institutional processes and student support services. Finally, Umer et al. (2023) examined the current state of predictive analytics in higher education, and in their work, they identified opportunities, challenges, and future directions for leveraging predictive modeling to enhance student success and institutional effectiveness.

Theme 5:

The fifth theme considers the adaptive assessment system. The following recent publications shed clarity on multiple dimensions of adaptive assessment system: (González-Calatayud et al., 2021; Hooda et al., 2022; Kumar, 2023; Gardner et al., 2021; Cope et al., 2021). González-Calatayud et al. (2021) provided a comprehensive systematic review highlighting the potential benefits of AI in student assessment. Hooda et al. (2022) investigated practical applications of AI for assessment and feedback to enhance student success in higher education contexts. Interestingly, Kumar (2023) investigated the implications of faculty members' use of AI in evaluating student papers. In contrast, Gardner et al. (2021) critically examined whether AI represents a real breakthrough or merely an exaggerated advance in educational assessment. Finally, Cope et al (2021) explored the impact of AI on general knowledge acquisition and its assessment within AI-based learning environments.

Theme 6:

The last theme is about the curriculum recommendation system. The following recent publications explore diverse angles of curriculum recommendation system: (Urdaneta-Ponte et al., 2021; Zhang et al., 2021; Raj & Renumol, 2022; Saito & Watanobe, 2020; da Silva et al., 2023). Urdaneta-Ponte et al. (2021) conducted a comprehensive systematic review that highlighted the potential benefits of AI in content recommendation for education. One year later, Raj & Renumol (2022) conducted a systematic review of the literature specifically on adaptive content proposals, focusing on their importance in tailoring learning experiences to individual students' needs. One year ago, Silva et al.

(2023) conducted a systematic review of the literature on educational recommender systems, providing insights into research trends and opportunities in this area. Zhang et al. (2021) delved further into practical applications of AI in recommender systems, focusing on its role in personalized learning environments. Finally, Saito and Watanobi (2020) further explored the development of learning path recommendation systems with a particular focus on programming education, highlighting the importance of tailored content recommendations in specialized fields.

To sum up, based on the literature review, the presented themes above are the recommended systems of AI-based architecture in higher education. The selection of these systems is a result of the high citation factor of references in each theme.

Significance of the Six Key Themes:

This section elucidates the significance of selecting each system within the classified themes as the primary component of the proposed holistic AI-based architecture in higher education, as outlined below:

Theme 1:

Traditional tutoring requires significant time and effort from the teaching staff. Through the integration of AI and data analysis, the AI-based intelligent tutoring system (ITS) provides support to higher education educators. The ITS system provides personalized and adaptable instructions to individual learners to simulate the role of a human teacher more efficiently. It is a system capable of delivering personalized learning experiences, providing immediate feedback, and adapting instruction based on student performance and needs (Alam, 2023; Mousavinasab et al., 2021; Conati et al., 2021; Guo et al., 2021; St-Hilaire et al., 2022; Eryılmaz & Adabashi, 2020).

Theme 2:

Traditional education is designed in a one-size-fits-all way. There is a fact that says every person has a different and special style of education. Integrating personal education based on AI into the education structure will enhance specialized education, as the AI-based personalized learning system aims to design the learning experience according to the student's individual preferences, needs, and learning styles. This system provides personalized learning pathways, content and activities, allowing students to progress at their own pace and receive targeted support. AI-based Learning systems utilize a variety of AI technologies to improve the learning experience (Tapalova & Zhiyenbayeva, 2022; Bhutoria, 2022; Whalley et al., 2021; Alamri et al., 2020; Rane et al., 2023; Essa et al., 2023; Chang et al., 2023).

Theme 3:

To enhance the personalization of education, and based on what we concluded in the literature review, we adopt an AI-based virtual learning system in our proposed comprehensive education infrastructure as it supports and complements distance learning environments. The virtual learning system provides personalized instruction and interactive learning experiences through online platforms, digital tools, and immersive resources (Wang et al., 2023; Rudolph et al., 2023; Hannan & Liu, 2023; Mohd Rahim et al., 2022; Dempere et al., 2023).

Theme 4:

The focus of the AI predictive analytics platform in higher education is to improve student outcomes and institutional performance through data-driven insights. These systems analyze diverse data sets using AI techniques to provide actionable recommendations and guide decision-making (Doleck et al., 2020; Luan et al., 2020; Gao et al., 2021; Fischer et al., 2020; Teng et al., 2023; Umer et al., 2023).

Theme 5:

The AI-based adaptive assessment system in higher education specializes in providing personalized assessments that adapt to individual students' abilities and learning paths. These personalized assessments adapt to individual students' abilities and learning paths through digital platforms, leveraging AI algorithms to dynamically adjust assessment items based on student responses (González-Calatayud et al., 2021; Hooda et al., 2022; Kumar, 2023; Gardner et al., 2021; Cope et al., 2021).

Theme 6:

The AI content recommendation system in higher education delivers personalized educational resources tailored to individual preferences and interests. Using AI algorithms, this system analyzes user data and content metadata and provides relevant recommendations through digital platforms and learning management systems (Urdaneta-Ponte et al., 2021; Zhang et al., 2021; Raj & Renumol, 2022; Saito & Watanobe, 2020; da Silva et al., 2023).

IV. Holistic Architecture of AI-Based Systems in Higher Education:

In this section, a holistic AI-based architecture is proposed for higher education, informed by the literature review conducted in the preceding section, as illustrated in **Figure. 1**. The architecture incorporates the systems introduced in the preceding themes. It is noteworthy that the studies reviewed in the literature section underscored the significance of all AI systems introduced in the themes. Consequently, these systems have been

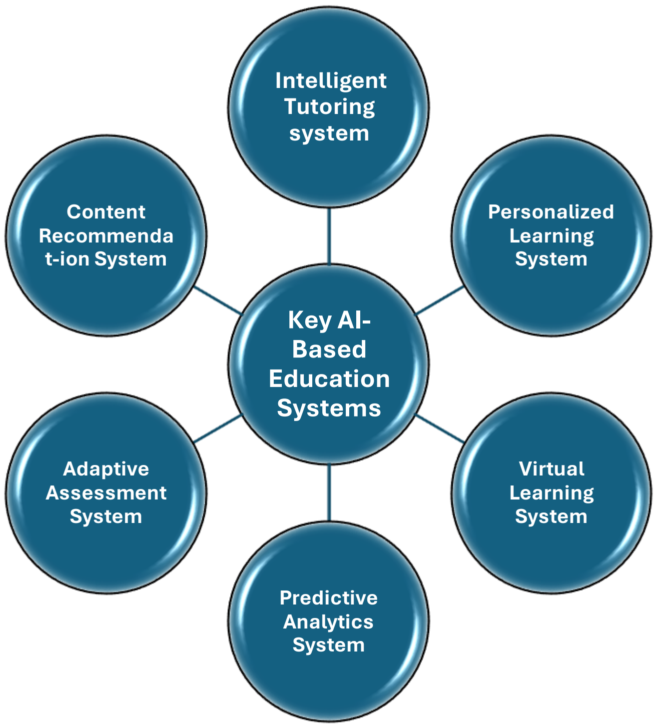

Figure. 1: Key AI-Based Higher Education Systems

integrated to construct a comprehensive AI systems architecture for higher education. In the subsequent subsections, informed by the literature, the AI-based systems are listed, and the AI technologies associated with each are introduced, where the associated technologies for each theme are depicted in **Figure. 2**.

AI Intelligent Tutoring System:

From the literature defined in ***Theme 1***, AI-based technologies are defined for ITS in this part, as shown in Figure. 2. These technologies are used in intelligent tutoring systems to improve the learning experience, the most important of which is ML, where ML algorithms are used to evaluate student data and design instructions accordingly according to the individual style, preferences, and performance of each student. There is also NLP technology that enables the system to understand students' inquiries and inputs and respond to them using natural human language and in several languages, where interactive interactions and conversation are enhanced. Also, obtaining insights into student learning behaviors from analyzing data, identifying areas of difficulty, and monitoring progress over time is one technique that can be adopted under this system's framework. Difficulty level, pace and teaching content can be adjusted dynamically based on student performance and real-time feedback through adaptive algorithms to ensure a personalized learning journey. Finally, to enrich the capabilities of this system, the integration of deep learning models such as neural networks is considered progress towards obtaining more complex and accurate interactions with students.

AI Personalized Learning System:

The literary group for ***Theme 2*** identified the technologies that enhance this system as follows, as shown in Figure. 2. Without a doubt, ML is the first one, where ML algorithms are used to analyze student data, predict learning preferences, and adapt instructions and recommendations for each student's special learning path. NLP is also indispensable, as it is used to enable this system to understand and respond to students' learning inquiries and inputs, thus also enhancing interactive learning interactions and conversation. In addition, data analytics are used here to extract insights about the student's learning behavior, monitor his learning progress, and identify areas for improvement. Finally, a recommendation system that uses recommendation algorithms to suggest personalized educational resources, courses, or educational activities based on the student's profiles and preferences.

AI Virtual Learning System:

From the literature review in ***Theme 3***, the most important technologies in virtual learning systems are extracted, which are: ML systems, NLP, and data analysis, as shown in Figure. 2. These technologies analyze student data, understand student questions and input, gather insights into student learning behaviors, track progress, and identify areas for improvement through data analysis, as explained in ***Theme 1*** and ***Theme 2***. In addition to the basic technologies above, virtual reality (VR) and augmentation reality (AR) technologies add an element of excitement to higher education as they are an interactive, illustrative educational method that helps students understand difficult concepts. These technologies also help create immersive learning experiences, allowing students to interact with digital content and simulations in a safe virtual environment.

AI Predictive Analytics System:

The primary AI technologies used in predictive analytics that were extracted from the literature reviews in ***Theme 4*** in the previous section are ML and NLP, as shown in Figure. 2. Additional special technologies are deep learning and big data technologies. The focus in this ***Theme 4*** is on special technologies. Deep learning uses neural network techniques to handle complex data structures and extract meaningful features from large sets of data, enhancing the accuracy and predictive power of learning models. Big data technologies are used, such as computing frameworks, to efficiently process and analyze large amounts of data.

AI Adaptive Assessment System:

The reviewed literature in ***Theme 5*** presented the main technologies used in the AI adaptive assessment system, as shown in Figure. 2. The primary AI technologies used in the AI adaptive assessment system in higher education are ML and of course NLP. The ML algorithms in this system create adaptive assessment items tailored to individual learning paths. NLP is used to analyze students' answers in oral and written exams and the tasks assigned to them, such as reports, research, and graduation projects, provide insights into the students' logical thinking process, and enable the system to provide feedback and support to learners. There are also technologies associated with big data, which in turn are used to analyze large amounts of student assessment data, identify patterns, and improve the assessment algorithms used to improve accuracy and reliability. This system is distinguished by a technology or subsystem of this system, which is the item response theory (IRT) system. This system is used to calibrate assessment items and assess students' abilities based on their responses. This enables the assessment system to select appropriate items and accurately assess the student's competence.

AI Content Recommendation System:

There are AI technologies used to facilitate this system's tasks, extracted from the literature on Theme 6, as shown in Figure. 2. The basic technology used in this system is NLP. NLP is used to analyze textual content such as major course descriptions or learning objectives to extract semantic information and improve content relevance and accuracy of recommendations. The technologies for ***Theme 6*** are collaborative filtering, content-based filtering, and hybrid methods. Collaborative filtering employs algorithms that analyze user interactions and preferences and recommend content like items that similar users have previously liked, viewed, or accessed. In content-based filtering, algorithms analyze the attributes and features of educational resources, for example, keywords, topics, and metadata, to recommend content that matches users' interests and preferences. Finally, hybrid methods are a combination of collaborative filtering and content-based filtering to provide more accurate and diverse recommendations that consider user preferences and item characteristics.

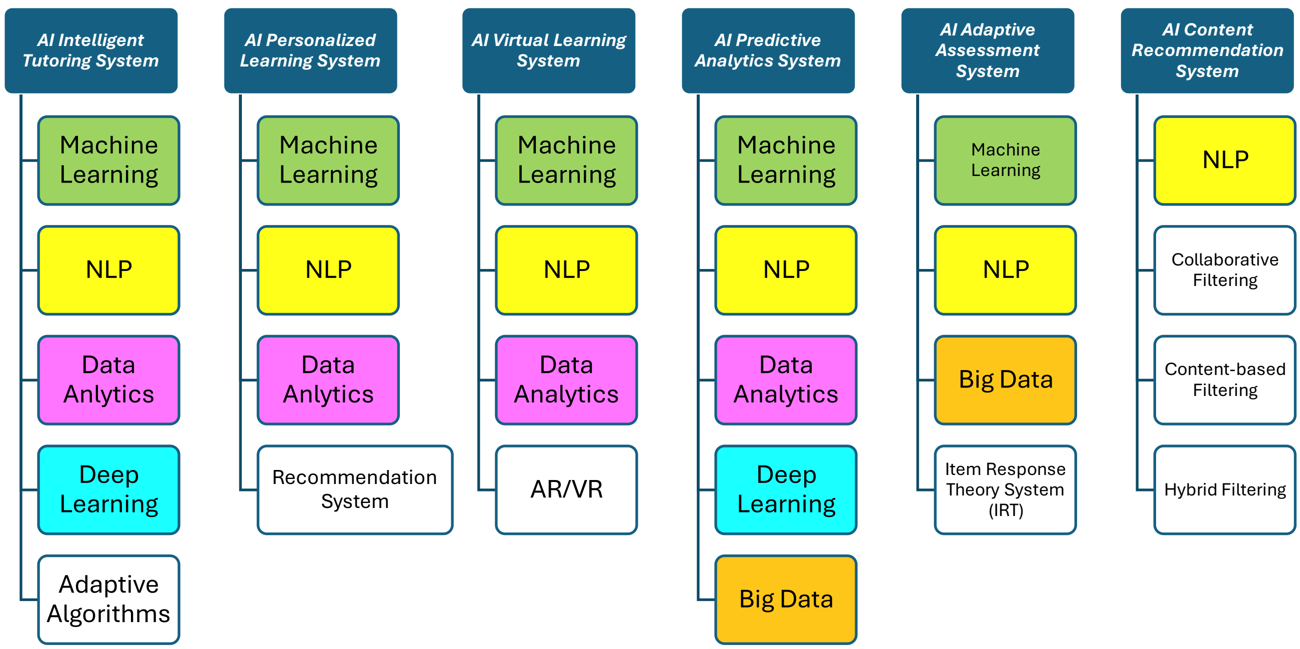

Figure. 2: AI-Based Education System - AI technologies

V. Challenges and Limitations of AI-based Systems in Higher Education

Despite what the AI-based systems offer, there are many challenges facing them that must be addressed. The challenges are summarized in this section. The first challenge is designing and implementing the system, which requires experience in AI, ML, and educational psychology. These are the technical requirements that must be available to enable the system in any scientific institution. Getting a system aligned with curricula and teaching practices requires careful coordination and alignment. There are also ethical considerations that must be considered, including the privacy of student data and the bias of the algorithms designed for this system. Technology contributes to exacerbating educational inequality. Lack of social and emotional support when communicating and guiding students, as human interaction is necessary to motivate the student and provide human support to the student. The guidance and personal contact provided by human teachers cannot be replaced. The final challenge is scalability and accommodating large numbers of students and diverse learning environments. Data quality and availability also is a challenge, where the accuracy of the AI models depends on the data quality and availability. The poor-quality data or insufficient data can lead to inaccurate predictions. AI models are complex, especially deep learning models. It is difficult to understand and thus trust the underlying predictions. Overfitting is also one of the things that the predictive systems may suffer. The models learn to memorize the training data rather than generalize to new data. This leads to poor performance on unseen data.

VI. Conclusion

The holistic AI-based architecture in higher education is drawn based on the systematic literature review of the recently adopted higher education systems. From the well-known "Google Scholar" library, the highly cited and reputed literature has been reviewed. From the systematic review, six themes have been concluded: AI Intelligent Tutoring System, AI Personalized Learning Platforms, AI Virtual Learning System, AI Predictive Analytics System, AI Adaptive Assessment System, and AI Content Recommendation System. The significance of each system under each theme is defined. Each system is adopted as a main part of AI-based higher education architecture. The final version of the AI-based architecture in higher education is proposed. The AI technologies under each system are explained. This paper gives the stakeholders an accurate and recent view of the future of AI-based higher education, to help make the right decision regarding modern educational methods based on AI. The future work will focus on addressing the challenges and limitations of implementing AI-based architecture in higher education.

Theme 3. Cultural Exchange in a Globalised World

The effects of the multiple facets of culture on mental health: A focus on globalising and evolving agents

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Abstract:

This paper aims to explore the effect of multicultural environments on the mental health of individuals by analysing the influence of different facets of culture on mental health, considering the varying sociocultural contexts and the different social determinants.

The current conceptualizations of culture do not consider a global perspective. Hence this study develops a more global lens to study culture and how a global aspect might be igniting new mental health concerns. The study pertaining to the value pyramid (Shakeel, 2021) is used to model the different facets of culture namely: traditional, transitionary and global. These facets identified within and across these classes are linked to mental health problems through the careful examination of the social determinants pertaining to each specific facet of culture including (a) the social structures of the classification and its inherit bonding designs (b) stress levels connected to societal roles (c) associating coping mechanisms and (d) types of social support. The manifestations of these four characteristics in the three classes lead to formulation of six hypothesis associating distinct cultural facets with mental health issues. The appropriate choice of factors constituting mental health might be subject to change like culture itself, that remains a fundamental dilemma.

We use the notion of cultural facets and posit that the elements within this classification influence mental health problems differently. Our preliminary findings suggest that the traditional cultural classification is predicted to have less frequent mental health issues as compared to a more global culture; however, the global culture moves towards reduced stigmatization and offers rigorous, individual remedial measures suitable for sustainable long term stability.

This study explores the classification of culture with disregard to individual contextual circumstances. Individual contextual circumstances have an important role as mental health detriments (Maté, 2022) which can be explored better in an empirical study. We suggest various potential circumstances as recommendations for future empirical research including individual differences relating to socioeconomic status, gender roles, ethnic origins and generational differences.This study suggests that culture needs to be studied using a broader global lens. A global lens helps understand the changing discourse of culture and how it can manifest itself in different mental health problems.

This study, using a global model, stresses the importance of linking new globally grounded behaviour as antecedents of mental health problems. The consideration of culture, as fluid in nature, helps in better understanding the emerging mental health concerns.

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Theme 5. Environmental Challenges

Sustainability leadership – leadership in a new reality

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Abstract:
The concept of sustainability as introduced by the UN report Our Common Future is defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". In 2000, the UN Global Compact issued "a call to companies to align strategies and operations with universal principles of human rights, labor, environment and anti-corruption, and take actions that advance societal goals". The introduction of the Sustainable Development Goals brought some goal clarification, but also presented new challenges. Current models of leadership are not suitable to address these challenges. How do our notions of leadership need to change to manage the transition to sustainable business?
Leadership theory has evolved from trait-based to transformational to servant leadership theories; a more recent focus has been a turn from leadership to followership theories. The desire to embrace a new business model based on sustainability requires a new approach to leadership.
In this conceptual paper, we explore the paradigm shift needed for sustainability leadership by applying a negative epistemology. Rather than trying to clarify what "sustainability as a business model" asks from leadership, we suggest that eliminating what we can expect not to be sustainable and therefore not to be included in the leadership needed to achieve a sustainable business model, provides more insight into what sustainability leadership is.
We do know that sustainability is systemic and thereby requires a paradigmatic change approach. Conducting a change program is difficult enough, but when it involves a paradigm shift, it has become exponentially harder. The paradigm shift has to allow for transformation in multiple areas of the business at the same time resulting in a call for leadership.

Introduction

The concept of sustainability has evolved to meet the needs of advancing societies. From the Brundtland definition (1987) of sustainability, “meet the needs of the present without compromising the ability of future generations to meet their own needs,” to the much more specific notion of the Sustainable Development Goals (UN Agenda 2030, 2015), the shifts in the conceptual framework force entities to reevaluate their core values and their leadership structure. We propose a new conceptual framework of leadership for sustainability which we hope will dismantle outdated perceptions of leadership and propel a new one which highlights the interconnectedness of the individual, the organization and the larger, changing world. We perceive leaders as visionaries, yet traditional leadership models measure their value by their ability to achieve the “right” results. Current domestic leadership models address characteristics of leadership mainly within an organization. And although global leadership takes into consideration the complexity in which global business operates, the assessment of a leader within this model is focused solely on their leadership within the business (Stahl, Pless, Maak, & Miska, 2018). Even when the organization is perceived as an open system, and leadership as interactional, the current models do not take into consideration the complexities that arise when stakeholders are defined in a much broader network of interest groups. Often, shareholders are prioritized, even when a stakeholder approach is used, or stakeholders are defined in a narrow sense. Furthermore, corporate time horizons do not accommodate long-term environmental and social well-being. Therefore, even within the context of modern sustainability leadership models, the embraced goals and visions typically fall within business-as-usual models. The role of business in sustainability efforts is dynamic and encompasses not only environmental but also social and cultural dimensions. Seeing the basic goal of sustainable business as addressing a triple bottom line (Elkington, 1997), we propose a new approach to leadership that focuses on the transition needed to achieve the audacious goal of empowering leaders as true visionaries who are tasked with sustainable development. This shift requires a mindset change, a new understanding of leadership that includes individuals at all levels who are empowered to contribute solutions and foster a culture of shared responsibility for the well-being of our planet and the ethical future of humanity. The leadership framework that we envision involves three interlocking dynamics: the individual, the organization with purpose, and the wider reality. The person leading from the envisioned model must simultaneously make sense of all three realities and achieve results in all three. We bring our approach using via negativa to the forefront of our assertion by offering our methodology first. By doing so, we hope to shed light on the new aspects of leadership for sustainability that have not yet received enough attention. Then, we address current leadership insights in the literature review to examine the shortcomings of existing models. Finally, we present our new conceptual framework of leadership for sustainability. We conclude with an outlook and provide suggestions for future research.

Methodological approach

For over a year, we met regularly and engaged in collaborative exploration by sharing our interest in sustainability, stakeholder management and leadership. Our different backgrounds in philosophy and global leadership allowed us to create a space of inquiry and growth, as we constructed a framework grounded in qualitative research methods. We used dialogic inquiry to deepen our understanding of this topic by actively contributing to and reflecting on our conversations to construct new knowledge in collaboration. "Meanings and understandings are progressively constructed over time as events and ideas are revisited, extended, and reflected on in the discourse" (Wells, 2015, p.8). These conversations inevitably led back to our curiosity about the challenges leaders face when tasked with embracing business as a force for societal good (Cooperrider & Selian, 2022). Since we agreed that "leadership" and "sustainability" are not well-defined terms, (Northouse, 2021; Elkington,1997) we quickly embraced a via negativa approach during our inquiry sessions. This approach is based on a philosophical tradition (Carabine, 2015) that goes back to the cave metaphor of Plato wherein the men in the cave realize that they do not see reality, but shadows. This perception of an altered version of reality applies to the definition of sustainable development often used: "meet the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p. 54.) Since a sustainable future only exists in our imagination, we can't rely on empirical knowledge to guide our approach. Rather, we focused on eliminating what we know is not sustainable and simply what cannot be when we conceptualize how to lead for sustainability. With this via negativa mindset, we developed the conceptual framework presented here.

Literature Review

In this section we provide brief summaries of traditional leadership theories and sustainability in business to explore the intersection of leadership and sustainability. We identify the need for a new approach to leadership for sustainability by showing the limitations of traditional leadership models. In addition, we highlight emerging trends in leadership theories that address leadership for sustainability.

Traditional leadership theories

Current leadership theories originating in scientific research have been around for at least 100 years (House & Aditya, 1997; Andersen, 2016). Early theories, such as trait and behavioral theories, focused on identifying the inherent qualities and characteristics of effective leaders and certain leadership traits continue to play a major role in our understanding of leadership effectiveness. The Big Five theory provided a framework to better research traits (Judge, Bono, Ilies, & Gerhardt, 2002). Trait and behavioral theories suggest that leadership can be developed. The field evolved and shifted towards contingency theories that consider the situational variables influencing leadership effectiveness. Fiedler's Contingency Theory states that leaders are either task-oriented or relationship-oriented and that their leadership style is fixed (Fiedler, 1967). While House (1971) in his Path-Goal Theory suggested that leaders can change their style and behavior and thereby enhance follower performance and satisfaction. Contemporary theories, such as transformational leadership, further expand our understanding by examining how leaders can inspire and motivate followers (Bass, 1985; Northouse, 2018; Bass & Riggio, 2006). Servant leadership theory and followership theories (Greenleaf, 1998; Uhl-Bien, Riggio, Lowe & Carsten, 2014) suggest a more distributed approach to leadership, promoting a collaborative environment. With the line between leaders and followers blurred, they recognize the reciprocal nature of influence between leaders and followers. They advocate a focus on the greater good and the overall well-being of the organization or even the community. In summary, servant leadership and followership theories both emphasize ethical leadership, strong relational dynamics, the development and empowerment of individuals, and a collaborative approach to achieving the common good. Our theory is informed by many of the models discussed above. Each provides important insights into the multifaceted concept of leadership. The work determines what leadership will be most successful in achieving the goals. New goals – summarized here as sustainability goals – require a new approach to leadership. We look to the emergent fields of practice-based theory, especially practice-based management theory, and responsible management (Tengblad, 2012; Rasche, 2020). Practice-based theory often uses the terms leadership and management interchangeably. Mintzberg (2009) sees managers as leaders, and leadership as management practiced well. He is concerned with getting business executives to focus on critical societal issues and challenges them to not only attend to the evident conditions of social or environmental problems but to address the underlying cause of these problems (Mintzberg, 2019). As Andersen (2016) put it, leadership of organizations is about what you do and accomplish. If what you do and accomplish needs to change, leadership must change as well. We recognize that current approaches to leadership did not evolve to address societal issues. We are interested in understanding how our concept of leadership needs to change to address the global issues our world is facing and to lead organizations to where they are a force for good.

Sustainability in business

Only a few years ago, few fellow CEOs would have agreed with CEO Ray Anderson that business is a "major culprit in causing the decline of the biosphere" (Anderson, 2009). Today, global CEOs work together on some of the most pressing environmental and social issues in groups like the UN Global Compact (UNGC), the world's largest corporate sustainability initiative. The concept of sustainability and its dimensions are well-articulated in the Brundtland Report, formally known as "Our Common Future", published by the World Commission on Environment and Development (WCED) in 1987. The report provides one of the most widely recognized definitions of sustainable development: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987, p. 54). This definition has been foundational in shaping the understanding and implementation of sustainability globally now commonly framed as follows:

a) Economic Sustainability: This dimension focuses on maintaining the economic capital necessary to support a high quality of life and economic stability over time. It involves efficient resource use, ensuring economic activities are profitable and viable in the long term without depleting natural resources.
b) Environmental Sustainability: This aspect emphasizes the protection and management of natural resources and ecosystems. It seeks to minimize ecological damage, prevent pollution, and conserve biodiversity, ensuring that natural resources are available for future generations.
c) Social Sustainability: This dimension is concerned with maintaining and developing social capital. It involves promoting social equity, inclusion, and cohesion, ensuring that all individuals and communities have access to essential services, opportunities, and a good quality of life. The three dimensions have been integrated into concepts like the Triple Bottom Line of economic prosperity, environmental quality, and social justice, sometimes also referred to as people, planet and profit (Elkington, 1997). By integrating these dimensions, sustainability ensures a holistic approach to development.

The role of business in promoting sustainability

The SDGs acknowledge the interconnected nature of social, environmental and economic development and as such provide a systems-based perspective on sustainable development (Rasche, 2020). The business sector is called out as an important actor (UN Agenda 2030, para 67): Private business activity, investment and innovation are major drivers of productivity, inclusive economic growth and job creation. We acknowledge the diversity of the private sector, ranging from micro-enterprises to cooperatives to multinationals. We call upon all businesses to apply their creativity and innovation to solving sustainable development challenges. In 2000 the UN Global Compact (UNGC) was founded with the understanding that governments and nonprofits alone cannot achieve the MDGs (precursors to SDGs), and that business has a major role to play. Today member organizations commit to "take action in support of the Sustainable Development Goals" (UNGC Business Application). In a recent policy report, the OECD (2021) notes that while there might be a tension between financial and sustainability objectives in business, business is well suited to offer products and services that do not negatively impact biodiversity. "Firms of all size categories can find a business case for aligning their core business with the SDGs" (OECD, 2021, p. 28). In addition, many businesses are engaged in developing and producing new offerings that present business opportunities as well as creating value-add for society at large. Not only in the environmental area but also in the social area are businesses contributing to a better society, e.g. by eliminating child labor. The report concludes that "shifting to sustainability requires a comprehensive approach and structural changes in the firm's culture. It entails the strong commitment of corporate leaders" (OECD, 2021, p. 28). The business case for sustainability asks for financial payoff (Salzmann, Ionescu-Somers, & Steger, 2005). However, when business leaders take a systems-based perspective, they ask what role the business has in society and redefine the purpose of the business. This goes beyond looking for financial payoffs and addresses the fundamental question of which role business should play in society. Business leaders who ask this question understand the major role their organization can play in the global change to sustainability.

Current intersection of leadership and sustainability

While exploring responsible leadership, Adler and Laasch (2020) remind us that leadership is asking the question "To what end?" and then expand on that and ask, "Are we producing something that's of value to society?" (p. 100). Leaders cannot ignore larger concerns beyond their organizations but must take a stand on societal issues. As Adler puts it "the choice not to engage, to not think about an issue, the choice just to continue what we have done in the past, is, in fact, a choice" (Adler and Laasch, 2020, 102). It takes fearless leadership to move a business, the community in which it operates and by extension the world towards a path of sustainable development for the greater good of all. It requires system-level change. Traditional leadership models assume a mission, vision and goals for the business that can be achieved following a well-thought-out strategy and implementation plan. The focus is on business goals that are narrowly defined. Even in organizations where leaders adopt an open-systems perspective, the interaction with the external environment tends to serve those actors who provide the business with resources (Berglund and Sandström, 2013). Traditional leadership models assume that goals and direction can be defined so that the organization can follow. Adler, an expert researcher on cross-cultural leadership for many years, states that "we don't know how to act positively and collectively toward each other on a global level" and is "disappointed to see how little we've learned over the past 50 years, and how little of what we have learned can actually be put into practice". (Adler and Laasch, 2020, 105). Extant leadership models do not support leadership that is needed to address the big problems the world is facing today. We need leadership that takes a whole-world perspective. Additionally, sustainability needs "multi-stakeholder partnerships" as the primary vehicle for implementing the SDGs (UN Agenda 2030, 2015, goals 17.16 and 17.17; Rasche, 2020; MacDonald, Clarke & Huang, 2022). Current leadership models do not assume aspirational goals involving myriad partners. Sustainability efforts have shown success when charismatic leaders have focused on them in their agenda. Ray Anderson, founder and former CEO of Interface, Inc., was a pioneer in sustainable business practices and transformed Interface, a global carpet tile manufacturer, into a model of sustainability. He launched the "Mission Zero" initiative, aiming to eliminate any negative impact the company might have on the environment by 2020. Anderson's commitment to sustainability led to innovative practices like closed-loop recycling and the development of modular carpeting that reduced waste and extended product life. Another example is former CEO of Unilever Paul Polman who embedded sustainability into Unilever's core business strategy through the Unilever Sustainable Living Plan (USLP). Under his leadership, Unilever aimed to halve its environmental footprint while doubling its business. Because the USLP needed a different kind of leader and leadership, the Unilever Leadership Development Program (ULDP) was created (Polman & Winston, 2021, 85). Also, Yvon Chouinard, founder of Patagonia, has built Patagonia into a leading example of environmental stewardship in the business world. The company is committed to using sustainable materials, such as organic cotton and recycled polyester, in its products. Patagonia's "Worn Wear" program encourages customers to buy used Patagonia gear and trade in old items for repair and reuse, promoting a circular economy. These examples show the possibility to transform a business into a sustainable operation; at the same time, they highlight the limits of current thinking on leadership for sustainability. Anderson, Polman and Chouinard are pioneers of a new leadership approach for a business that understands its purpose to tackle the world's biggest challenges, such as climate change, inequality, and poverty.

The Need for a New Approach

By identifying the gaps and inadequacies of the current approach, we introduce our own contribution to the evolving field of leadership for sustainability. In short, we agree with Visser and Courtice (2011, 3) that "leadership for sustainability is not a separate school of leadership, but a particular blend of leadership characteristics applied within a definitive context". The gaps we have identified in the traditional approach to leadership can be summarized as follows:

a) Narrow definition of the purpose of business; failure to embrace ethical approach
b) Linear approach to leading businesses
c) Narrow definition of stakeholders, incl failure to integrate stakeholder-centric approach
d) Inadequate time horizon (short-term focus)
e) Centralized, positional leadership mindset

These gaps lead us to identify the following principles for our framework of leadership for sustainability:

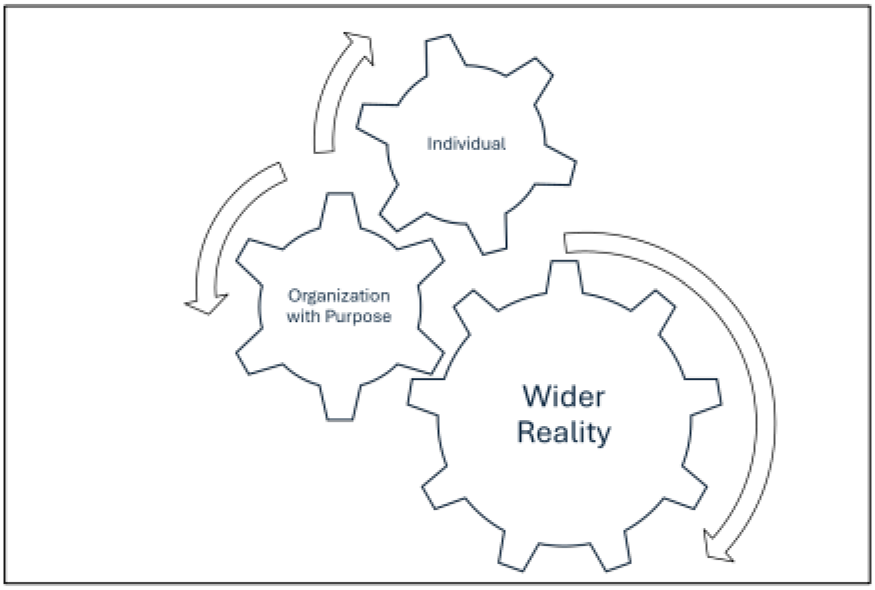
a) Ethical grounding and values-driven decision-making
b) Systemic thinking and adaptability
c) Awareness of the whole stakeholder context
d) Visionary and long-term focus
e) Inclusive and collaborative leadership mindset

The framework, its elements and principles are explained in the next section.

Conceptual framework of leadership for sustainability

With recognition of established extant leadership theories and visions of sustainability as discussed in the previous section, we now offer a new framework of leadership for sustainability. The new framework was developed from the assumption that leadership needs to meet a particular situation. Nevertheless, in our framework, three proposed realities closely intertwine and interact. The impetus of one reality directly influences the others.

Figure 1. Conceptual framework of leadership for sustainability



To begin with, we see leaders in this framework as individuals without focusing on the unique qualities of the individual. We recognize the wider reality in which the leader's vision is both grounded and responsive to. The final reality, the reality of the organization with a purpose, connects the leader with the wider reality and envisions the organization within a wider stakeholder context. While older models of leadership emphasize the uniqueness of a particular individual, the proposed model places the individual in a stakeholder context, putting more emphasis on the relationships than on the uniqueness of an individual. The leader's role is to foster a sustainable mindset throughout the organization which borrows from a trait approach to leadership and requires the leader to have a wider moral expansiveness (Crimston et al, 2016). Stakeholder leadership builds on the purpose of the organization, and in our model, this is shared with those who expect leadership (Kempster et al, 2011, Bass & Riggio 2006). Current theoretical constructs cannot solve the myriad sustainability agenda challenges that societies and economies are scrambling to address. That is why our framework requires a complete paradigm shift in both leadership and in the collective expectation of who and what a leader feels responsible for. This paradigm shift is reflected in our assertion that the framework is based on leadership within three realities. In addition to the three elements, we identified five principles that allow the framework to represent leadership for sustainability:

a) Ethical grounding and values-driven decision-making Embracing the ethical dimension of the sustainability agenda promotes leadership that is informed by this focus. While older models of leadership already had an ethical component, we propose that the ethical dimension is the soul of sustainability development (Bottery, 2014). This grounding of ethics promotes leadership with a greater sensitivity to moral expansiveness.
b) Systemic thinking and adaptability Older models of leadership have tended to be limited in focus. Today, with increased complexities and interdependencies common to sustainability concerns, leadership for sustainability requires systems thinking (Palaima et al, 2010). A holistic perspective based on an understanding of how different components of a system interact and influence each other is needed.
c) Awareness of the entire stakeholder context We extend traditional definitions of stakeholders to include non-humans, animals, natural resources and entire ecosystems found on earth. Since this awareness is central to our framework, we devote our next section to expanding on this principle.
d) Visionary and long-term focus The emphasis of the wider reality in our framework compels the leader to formulate and communicate a vision with the intent of inspiring others while progressing far into an unknown future. This contrasts with traditional short-term strategies and localized focus which exist in many industries and models.
e) Inclusive and collaborative leadership mindset Emerging theories of leadership such as servant leadership (Khan et al, 2021; Greenleaf, 1998) that are grounded in inclusivity and collaboration are more appropriate for leadership for sustainability than older, established models. With a paradigm shift, as explained above, the three realities work together guided by the five principles. As indicated above, a new approach to stakeholder engagement is central to our framework of leadership for sustainability. We are now going deeper into a discussion of stakeholder leadership and sustainability.

Stakeholder Leadership and Sustainability

Some of the challenges we are addressing in this section have to do with the context of leadership; and while they may differ in degree of intensity, it is beneficial to consider challenges derived from the international arena in which the firm is operating. Other challenges may be more universal to leadership, such as how to convince others to participate in a change program which they are uncertain of. At any rate, the most important challenge is probably direction. When it comes to sustainability, the vision has to be extrapolated from assumptions of the unknown future and then articulated to overcome resistance and get buy-in. Sustainability leads onto a road to an undefined destination. While collective admiration of leaders as heroes has been gauged by how accurately they envision the future, our definition of leadership challenges the assumptions of reality in the changing landscape towards an unknown future. Another obstacle lies in governance. In publicly traded companies, Board members answer to current shareholders and make sure the company remains attractive to future shareholders. Often, policies towards sustainability are slowed down or even canceled when Board members fear that they cannot convince the shareholders. We use Freeman's (1984, page 46) definition of "stakeholder": "A stakeholder is a group or individual who can affect or is affected by the achievement of the organization's objectives." When we interpret "objectives" as "sustainability objectives," then the leadership involved becomes more extensive. Understanding stakeholder interests and developing relationships with stakeholders transcends beyond the formal relationships companies maintain with stakeholders such as shareholders, suppliers and governmental agencies. The analysis of a sustainability agenda invites a wide understanding of the leadership's vision for the "commons," as introduced by Hardin (1968). The Theory of Common Pool Resources (CPRs) already recognizes the limited availability of commons such as the earth's natural resources, which are vulnerable and finite. We extend this theory by emphasizing how leadership needs to expand what is cherished, precious and shared. Stakeholders include people, and these days also animals and even ecosystems. This brings us to a new phenomenon in stakeholder management, the relationship with non-human stakeholders. In recent years there has been growing attention to recognizing rights of "non-human entities'' (Sartasuaso, 2015). Sustainability requires leadership to consider animals, plants and even entire ecosystems as stakeholders. This poses new and obvious challenges, such as difficulties in communicating. An example of this specific set of barriers can be found in the recent experiences of the Netherlands train company, Prorail. The company experienced badgers building tunnels under the tracks. Cleverly, Prorail selected specialized biologists as representatives for the badgers and collaborated with them to develop alternatives to meet the needs of the badgers (Prorail, 2016). This instance showcases innovation to include non-human stakeholders and address their interests. In leadership for sustainability, stakeholder management broadens from a narrow focus on those stakeholders who hold business resources to include the wider reality of society, including future generations and non-humans like whole ecosystems. Hence, the task of leaders becomes much more complex but not impossible.

Key Characteristics of Leadership for Sustainability

Leadership is usually sought out when a company (or any other social structure) is going through a change process. And historically, the more complex a change process, the more intense the leadership challenge. Certainly, for a sustainability agenda, the reason for leadership is both urgent and complicated (e.g. Burnes & By, 2012). Sustainability requires rethinking the familiar approaches to all human activity. As in all change initiatives, the existing approach needs to be examined and replaced by a better alternative. This can be a painful process, as the existing approaches were at least familiar. Most people involved had invested in them, both emotionally and in terms of acquired skills. Another characteristic of sustainability that relates to leadership is that it involves discussing and managing sensitive issues. We can see those issues come to light already with the Brundtland (1987) definition, which invites everyone to reflect on one's conscience, with an accusatory tone. Modern models of leadership, including the model proposed here, acknowledge that leaders who develop more extensive relationships with other people and entities deepen trust and empathy enabling them to address sensitive and challenging issues. Sustainability requires systemic change, which is more challenging than a linear solution and may be experienced as overwhelming. It requires a more holistic vision and, in connection with that, a more complex story to inspire others. This requires more developed leadership skills, such as visioning and personal mastery (Senge, 2006). It also requires more communication, because the holistic vision is projecting onto an unknown future. Sustainability requires the development of shared intent. The shared intent expresses the shared interests of everyone, and everything related to the commons. This shared interest unites all people and all realities on the planet and perhaps beyond.

Discussion and conclusion

There are several implications our conceptual model has for organizations and leadership development as well as for society at large. We hope that our suggested paradigm shift informs future research into leadership and sustainability.

Implications for organizations

Though specific aspects might differ, depending on industry and culture of the organization, common implications will bring the sustainability agenda to the forefront of each leadership model. Applying a via negativa approach, leaders will evaluate whether a particular course of action helps to shape a sustainable future or poses a challenge to it. This line of questioning may help to discover the organization's true purpose (Freeman et al, 2019), in the way in which a sculptor liberates a statue from the surrounding marble. The new leadership approach requires adjustments from leaders and other people who are involved. As indicated by Barrett (2011), it involved developing a new type of learning system within the organization. Other stakeholders will have to adjust their expectations from their leaders who are following this framework. The framework of leadership for sustainability highlights the interconnectedness of the individual, the organization and the larger world with all its stakeholders. Therefore, organizations need to evolve to embrace high levels of uncertainty and shift to organizational structures that foster collaboration with a wide network of stakeholders. This alteration echoes the trend found in goal 17 of the SDGs calls for strengthening global partnerships and cross sectorial and innovative multi-stakeholder partnerships to achieve the 17 goals by 2030.

Implications for leadership development

We identified ethical grounding, systemic thinking and a collaborative mindset as key skills and mindsets needed for leaders for sustainability. Ethics education, particularly in business schools, needs to be strengthened. The call for more ethics education is supported by an increased demand from business leaders (see, for example, Sigurjonsson, Arnardottir, Vaiman, and Rikhardsson, 2015) but more research is needed in this field. Additionally, leaders at all levels of the organization need to be better trained in systemic thinking. They need to understand how their actions impact ecosystems and people in faraway places and then develop ways to lead that are true to the ethical purpose of their own organization and the greater good.

Broader implications for society

The proposed model of leadership will change the societal context of the organization, as the leadership will be in many more, closer relations with various societal groups. As pointed out by Maak et al, (2006), the development of newer approaches to leadership has already gone in that direction, in responding to the issues of leadership, in line with what we've indicated, that require a new approach, and also the demands from the sides of social dynamics and political processes.

Future research directions

While we are encouraged by more recent explorations of leadership forms that have evolved from a central leader to shared forms of leadership, more research in collaborative, distributed models of leadership is needed to support the needs of true leadership for sustainability. Using a practice approach, i.e. starting with what leaders actually do, and including insights from research into global leadership effectiveness (Rickley & Stackhouse, (2022) will advance the field of leadership for sustainability. Our approach has been informed by research done primarily in the Western hemisphere using Western logic. We believe our conceptual framework of leadership for sustainability would benefit greatly from insights gained in other cultures, perhaps using non-Western logic. As we showed in our discussion of ecosystems and other non-human stakeholders, indigenous groups and governments in the Global South are leading the way for sustainability. More research here would strengthen our understanding of the wider reality, recognizing all stakeholders. Stakeholder management theory would need to include stakeholders who are not yet born.

Via negativa as a method to develop new knowledge

Finally, we recommend using a via negativa approach in leadership research to focus on possible obstacles for leadership for sustainability. This approach, especially when used in interdisciplinary research, promises to be very helpful by focusing on what must be removed from our current reality to preserve what needs to be protected.

As well as systemic, sustainability and the SDGs are universal in nature and global goals. To achieve them, result benefits from a shared effort. This suggests a better fit with leadership models that call for managing shared challenges by sharing leadership. Sustainability and the SDGs are global goals, and we can adopt shared leadership concepts from global leadership theory.

Finally, we explore the link to moral leadership since the SDGs express a moral responsibility not only towards the present generation but also towards future generations. We suggest that the SDGs represent virtues that require leadership based on a virtue perspective, e.g. curiosity and courage in exploring the new realities.

Theme 10. Education in a Globalised Era

Implementation of Eco-systems of Open-Science Schooling: Challenges and insights in four countries

GLOBALISATION
CONFERENCE

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Abstract:
The objective of the study is to identify the challenges in the implementation of the Ecosystems of Open Science Schooling (Eco-OSS) project as perceived by different stakeholders. The Eco-OSS Project, which started in October 2020, is to help secondary schools and science teachers change traditional science education classrooms to a collaborative and sustainable science learning environment through multiple activities in collaboration with educational institutes, families, enterprises and broader society partners, so that permanent ecosystems of open science schooling can be developed and sustained.
Four secondary schools from four European countries, i.e. Poland, Lithuanian, Romania, and Turkey, participated in the Erasmus+ project. The research was designed based on Vygotsky's Sociocultural Theory and Bronfenbrenner's Ecological Systems Theory. Data were collected from the interviews with 25 students, teachers, school administrators and ecosystem partners who participated in the project, analysed and visualised with the online analytical tool InfraNodus. The studies of four ecosystems show the shared structure of ecosystem and yet with own particularities in vision and methodology, and the visualisation demonstrates the common topics and knowledge gaps in the description of the participants about OSS ecosystems.
Insufficient alignment between traditional educational frameworks and the OSS model emerged as a significant challenge in the study of the four national and stakeholder groups. In addition, the direct application of OSS around topics like forestry, biodiversity, etc., has led to a tangible impact on student engagement and understanding of science in real-world contexts, as well as communicative and digital competence. The study identified a knowledge gap and research need, particularly on integrating OSS within standard curricula without disrupting regular schooling structure. The integration of OSS into existing educational frameworks calls for comprehensive planning, necessary resources, and strategic alignment with educational policies.

Introduction

In recent years, while technological advancements have rapidly transformed various industries, science education within primary and secondary schools has largely retained a compartmentalised and isolated approach. This traditional model has increasingly been subject to critical scrutiny. 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 science education 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.).

Building upon the foundations laid by the initial OSS project (2017-2020), the follow-up project emphasised the creation of vibrant learning ecosystems involving students, teachers, families, and external partners to address local scientific challenges and foster innovation. This project is called the Ecosystems of Open Science Schooling (Eco-OSS) project. It was headed by Wittenborg University of Applied Sciences, together with University of Eastern Finland as the knowledge partners, and Europe/Treballant amb Europa Associació from Spain. The project 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. 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.

To inform the development and implementation of Eco-OSS, a research component was integrated into the project. This study aimed to identify the challenges encountered during the implementation of Eco-OSS, as perceived by various stakeholders, and to explore potential solutions. By examining the experiences of four countries participating in the Eco-OSS project—Lithuania, Romania, Poland, and Turkey—this research contributes to a deeper understanding of the factors influencing the success of OSS initiatives. 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.

The theoretical framework underpinning this study draws upon constructivist learning theory, Bronfenbrenner's Ecological Systems Theory, and Vygotsky's Sociocultural Theory, particularly the concepts of the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD). The following sections will outline the research methodology, present the findings, and discuss their implications for the development and implementation of Eco-OSS.

Literature Review

Science education has been subject to criticism for failing to provide students with meaningful learning experiences (Montero, et al., 2019; Tobin, 1990; Tobin & Gallagher, 1987). Traditional approaches, often confined to textbooks and laboratory settings, create a disconnect between classroom knowledge and real-world applications. 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). Consequently, students develop a narrow perception of science as an isolated discipline, overlooking its pervasive influence on daily life (Lee & Wolff-Michael, 2002). Science is integral to human interaction, informing decision-making on health, environment, and societal challenges (Yacoubian, 2018). However, laboratory-based instruction has limitations in developing problem-solving skills and fostering a deep understanding of science's role in addressing societal issues (Tobin & Gallagher, 1987). To bridge this gap, students must engage with real-world scientific practices through community involvement and collaboration (Howaard & Mataheru, 2019).

The prevailing educational paradigm hinders Europe's pursuit of sustainability goals (European Commission, 2015; Scharmann, 2007), contradicting the EU's initiatives for a smart and sustainable future (European Commission, 2015). In an increasingly interconnected world, citizens require a strong foundation in science and technology to address emerging challenges (European Commission, 2015). To achieve this, science education must transcend school boundaries and foster partnerships with industry and the broader community (Montero, et al., 2019; European Commission, 2015; Lee & Wolff-Michael, 2002).

Learning is regarded as the process of constructing knowledge from sensory data and prior knowledge (Tobin, 1990; Kara, 2018). Constructivism posits 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). As Thomson (2018) emphasizes, knowledge acquisition is grounded in personal experience. Constructivist pedagogy prioritizes exploration, social interaction, and student-centred learning to facilitate knowledge construction (Driscoll, 2005). In addition, Moreover, connecting new information to real-life contexts is crucial for meaningful learning (Kamphorst, 2018; Suero et al., 2019). By engaging students with the world beyond the classroom, open schooling approaches can foster a deeper understanding of societal challenges and potential solutions (Howaard & Mataheru, 2019).

Vygotsky's Sociocultural Theory emphasizes the critical role of social interaction in cognitive development (Vygotsky, 1978). 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). Children acquire values, beliefs, and problem-solving strategies through engagement with more knowledgeable individuals within their community (McLeod, 2024). Tomasello, et al. (1993) identified three primary learning mechanisms: by imitative learning (copying another), instructed learning (learning from teachers) and collaborative learning (learning from peers). Central to Vygotsky's framework are the concepts of the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD). The MKO, not limited to adults or teachers, can be peers or even technology (McLeod, 2024). The ZPD represents the gap between independent and guided learning, highlighting the potential for cognitive growth through social interaction (Figure 2.1). This points out that social interaction and involvement in the community supports students' cognitive development as well as develops various skills and strategies (McLeod, 2024).

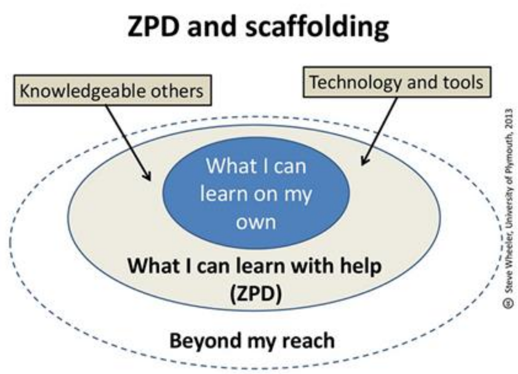

Figure 2.1. ZPD and Scaffolding (McLeod, 2024)

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. Interactions within the biological, familial, community, and societal contexts shape development (Bronfenbrenner, 2000). The model of Entrepreneurship Education Ecosystem (EEE) further illustrates this interplay, emphasizing the interconnectedness of curriculum, culture, pedagogy, physical environment, and motivation in the multidimensional ecosystem (Mueller & Toutain, 2015; Toutain et al., 2019) (see Figure 2.2).

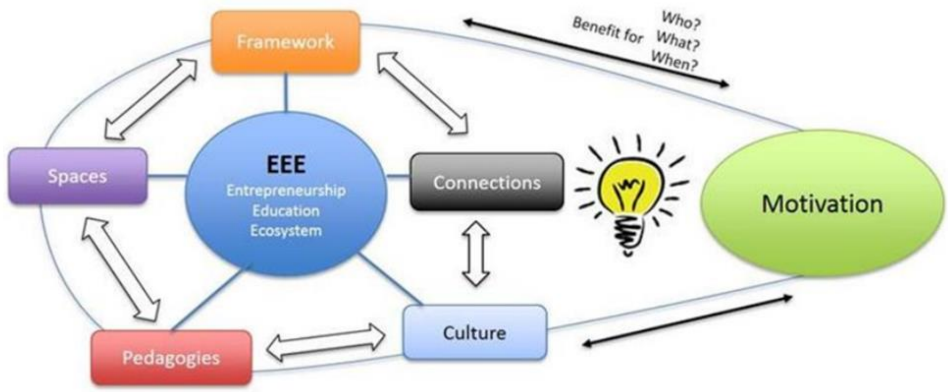

Figure 2.2. Dimensions & Dynamics of Entrepreneurship Education Ecosystems (EEE) (Toutain et al., 2019)

The Open Science Schooling (OSS) approach centres on community-based science missions. To facilitate the transition from traditional to mission-based science education, infrastructures of science resources (also known as ecosystems) should be made readily available to educators and schools. The Eco-OSS project aims to develop and test accessible science resource infrastructures (ecosystems) within partner communities, providing guidance for broader implementation in other schools in Europe. Research by Mulero, Grau & Torra (2019) indicates 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.

However, integrating OSS into practice presents significant obstacles, as highlighted by Mulero et al. (2019) and Mulero et al. (2022). A primary challenge lies in the mismatch between the fragmented subject-based structure of school curricula and the holistic nature of real-world problems. Rigid timetabling and bureaucratic hurdles further impede OSS implementation (Mulero et al., 2019; Mulero et al., 2022). While teachers recognize the potential of OSS to increase student engagement, they often encounter difficulties in its practical application. Moreover, securing stakeholder involvement is an ongoing challenge.

Research methodology

Research design

Our research was designed based on Lev Vygotsky's Theory of Cognitive Development, Urie Bronfenbrenner's Ecological Systems Theory, and the model of Entrepreneurship Education Ecosystem (EEE), with a focus on the challenges and facilitators among stakeholders during the implementation of the Ecosystems of Open-Science Schooling

(Eco-OSS). As planned in alignment with the research objectives, we focus on the following questions in the research:
Main research question:
What are the primary challenges and facilitators of implementing Ecosystems of Open-Science Schooling (OSS) in four selected countries?
Sub-research questions:

1. How do the specific socio-cultural, educational, and policy contexts of the four countries shape the implementation of Eco-OSS to engage students in science learning?
2. What are the key differences and similarities in the challenges encountered during the implementation of Eco-OSS across the four countries?
3. How do main stakeholders (teachers, students, parents, administrators, policymakers) perceive the impact of Eco-OSS on student learning, their motivations, roles and challenges in the implementation?
4. What strategies and supports have been most effective in overcoming implementation challenges and fostering the sustainability of OSS?

To answer the above questions, we designed the research in two parts. The first part focused on observing Eco-OSS implementation through reports, journals, photos, and videos collected from the four schools through basecamp.com, supplemented by a preliminary survey of 25 key stakeholders (13 students, 7 teachers, 3 school administrators, and 2 external partners). The survey covered participants' background information, local ecosystems and missions, newly acquired knowledge and skills, and the engagement and contributions of ecosystem partners.
The second part involved interviews with another group of key stakeholders. The interview questions for students focus on their experiences and engagement in the Eco-OSS missions. The interview questions for teachers 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?). The interview questions for the school administrators 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. The interview with external partners focuses on their motivation in supporting the ecosystems, their roles in the

implementation of the ecosystems, and challenges in the sustainability of it. Data from both parts were integrated to provide in-depth explanations for the research questions.

Participants of the study

The participants in the research are students, teachers, school administrators and Ecosystem partners involved in the project. We employed opportunity sampling, asking project coordinators in each national group to contact available and willing participants. Due to participants' busy schedules and pandemic restrictions, we offered flexible research involvement. Interviews were conducted in January and February 2022, following observations and a preliminary survey. An additional 25 participants, different from the initial survey group, were interviewed (see Table 3.1).

Table 3.1 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.

Data analysis

The WUAS and UEF research teams collected and analysed the data. Part 1 findings provide a background on challenges and insights among interviewed stakeholders for Part 2. InfraNodus analysed and visualized Part 2 data, highlighting thought and challenge features in the OSS ecosystems. This web-based, open-source tool employs text network analysis to identify influential words connecting different topics within a context (e.g., Feyissa & Zhang, 2023; Gunawan, 2024). It combines clustering and graph community detection to group densely connected nodes and those separated by structural gaps. GPT-4 AI is integrated to suggest questions, facts, and ideas based on text analysis.

After removing common conversational terms and repetitive, redundant, and irrelevant words, we uploaded the data to the website for analysis. The findings are reported in the following.

Results

Research findings are reported in two parts. An overview of the four ecosystems provides a background for the report of the analysis of the interview data.

Overview of four ecosystems

The four case studies of Romania, Lithuania, Poland, and Turkey provide diverse yet comparable perspectives on the implementation of Ecosystems of Open Science Schooling (Eco-OSS), as illustrated in Table 4.1. A common thread across all cases is the central role of the school as a hub for learning and collaboration. Each case study emphasizes the significance of partnerships with external stakeholders in enriching the educational experience. Furthermore, a core component of Eco-OSS is the shift towards experiential learning, involving students in hands-on activities and real-world problem-solving.

While the concept of an ecosystem is shared, the specific composition and scope vary across the cases. The Romanian and Polish schools in the research focus primarily on the school environment, while the Lithuanian and Turkish schools encompass a broader community. The extent of involvement and influence of external partners also differs. Despite these variations, all cases highlight the importance of student-centred learning and the benefits of collaboration.

Challenges encountered during Eco-OSS implementation include the transition to new teaching and learning approaches, time constraints, resource limitations, effective partner collaboration, and especially the impact of the COVID-19 pandemic. However, the positive outcomes for both students and teachers are evident. Students demonstrate increased motivation, engagement, and a broader skill set, while teachers experience professional growth and job satisfaction.

The successful implementation of Eco-OSS has the potential to create a more dynamic and engaging learning environment, fostering both personal and academic growth for students.

Table 4.1 Overview of the four OSS ecosystems

	Ecosystem and Mission Overview	**Open Science Schooling Implementation Outcomes**	**Ecosystem Implementation Outcomes**
Romania	The Romanian OSS ecosystem focuses on implementing an outdoor education ecosystem in response to COVID-19 restrictions, following a national campaign. The ecosystem comprises the school, students, teachers, parents, and multiple external partners. The primary goal is to create a conducive learning environment, addressing students' social, psychological, and academic challenges arising from the pandemic.	Outdoor learning fostered a sense of "classroom without walls," promoting motivation, active engagement, and better relationships with peers and teachers. Students gained autonomy, confidence, and curiosity. Teachers discovered students' hidden talents and the limitations of curriculum-focused teaching.	The ecosystem, led by an enthusiastic teacher, successfully implemented outdoor learning activities. Collaboration with external partners brought expertise, resources, and diverse learning experiences. The initiative fostered a more open school culture, though challenges related to teacher mentality and collaboration remain. The ecosystem had mutual benefits for all stakeholders, including improved student outcomes and enhanced partner visibility. Overall, the Romanian ecosystem highlights the potential of outdoor education within an ecosystem framework to address educational challenges and create positive learning experiences.

Lithuania	The Lithuanian OSS ecosystem is broad, encompassing students, parents, teachers, community, and external partners. It's focused on community needs, like environmental awareness and health knowledge. Students and teachers collaborate to identify local issues, transforming them into learning missions.	Open Science Schooling Implementation Outcomes Learning is seen as place-independent, emphasizing comfort and engagement. Students developed various skills, including communication, critical thinking, and research. Teachers also benefited, gaining confidence and broadening their perspectives.	Ecosystem Implementation Outcomes The ecosystem is problem-oriented, with students and teachers driving mission development. Outdoor learning fostered engagement, communication, and skill development. Partnerships with external organizations enriched learning experiences. Challenges included COVID-19 restrictions, managing student engagement, and adapting school administration.
Poland	The Polish OSS ecosystem is a blend of internal school dynamics and external collaborations. It emphasizes learning beyond the classroom, involving students, teachers, and external partners like universities. The primary goal is to motivate students, enhance their skills, and bridge the gap between secondary and higher education.	Learning is seen as flexible, occurring in various settings. Students developed a range of skills, became more curious and confident. Teachers also benefited from professional development. The focus is on experiential learning and developing positive attitudes towards science and the world.	The ecosystem is a combination of internal school initiatives and external partnerships. Collaboration is key, with universities playing a crucial role. Challenges include coordinating efforts and managing the transition to a new learning approach. The overall aim is to improve student achievement and foster a stronger connection between schools and universities.

Turkey	The Turkish OSS ecosystem views the school as a central hub connected to families, partners, and the wider community. Learning is seen as a collaborative process, with students, teachers, and external partners working together on problem-solving missions. The focus is on creating a supportive environment for student growth and development.	Learning is considered more effective outside the classroom, with students showing increased engagement and curiosity. Students developed a range of skills, including communication, teamwork, and research. Teachers became more open to collaboration and integrated partnerships into their teaching.	The ecosystem is driven by student-led initiatives, with teachers providing guidance. Partnerships with external organizations are valued for their expertise and resources. Challenges primarily arose from the COVID-19 pandemic, affecting planning and implementation. Overall, the focus is on creating a supportive learning environment through collaboration and experiential learning.

Visualisation and analysis of the interviews

In the following, we visualised and analysed all the answers in the interviews using InfraNodus network analysis (Paranyushkin, 2019; 2022) 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. 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. 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 4.2 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 4.2 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 (Table 4.2).

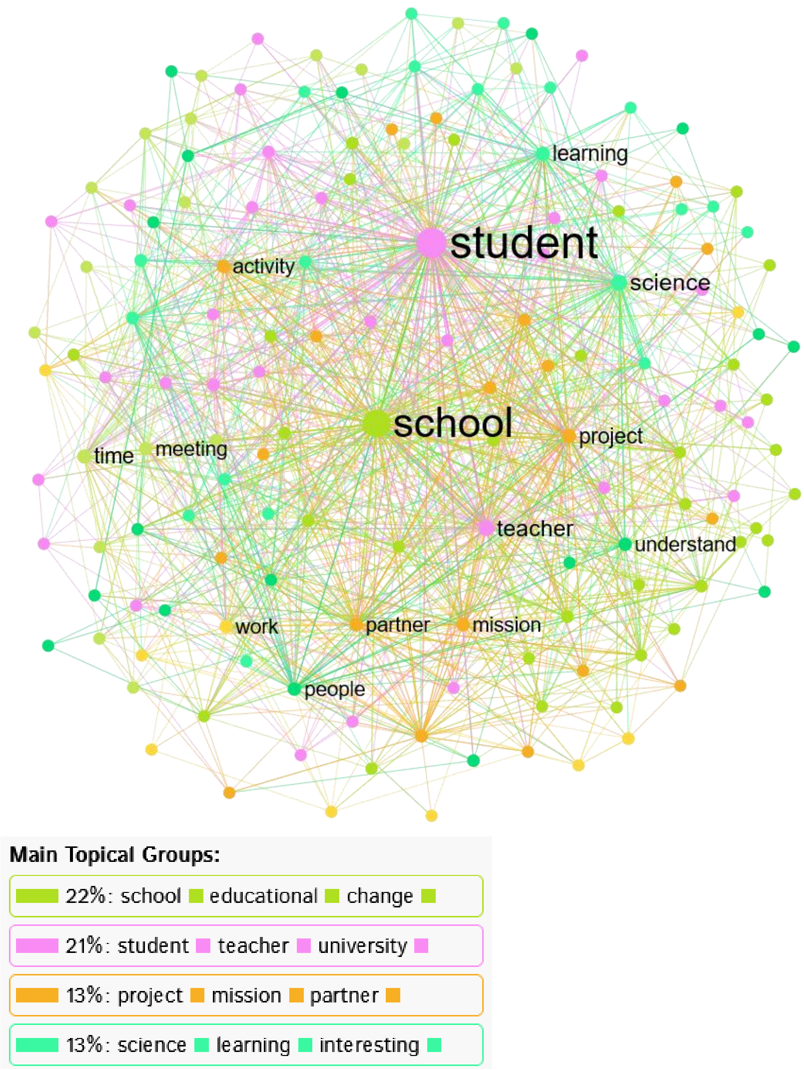

Figure 4.1 The network graph of all the interview data (source: InfraNodus)

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 4.1, 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.

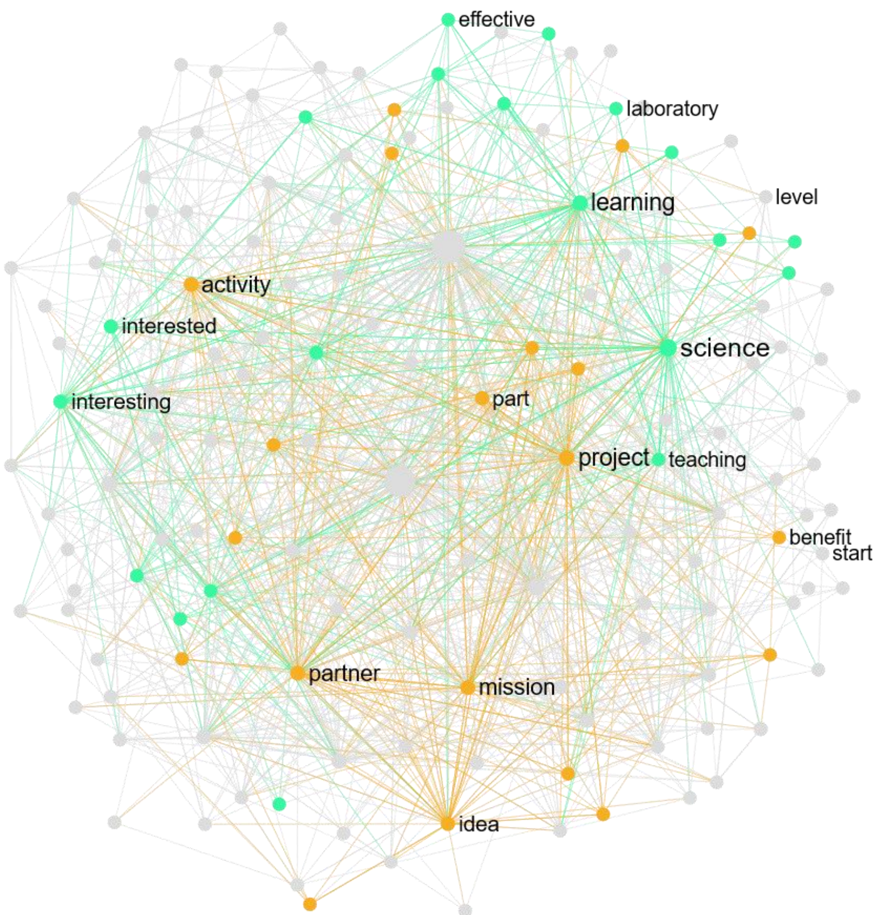

Figure 4.2. The structural gap in the whole group interview data

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 4.2). 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.

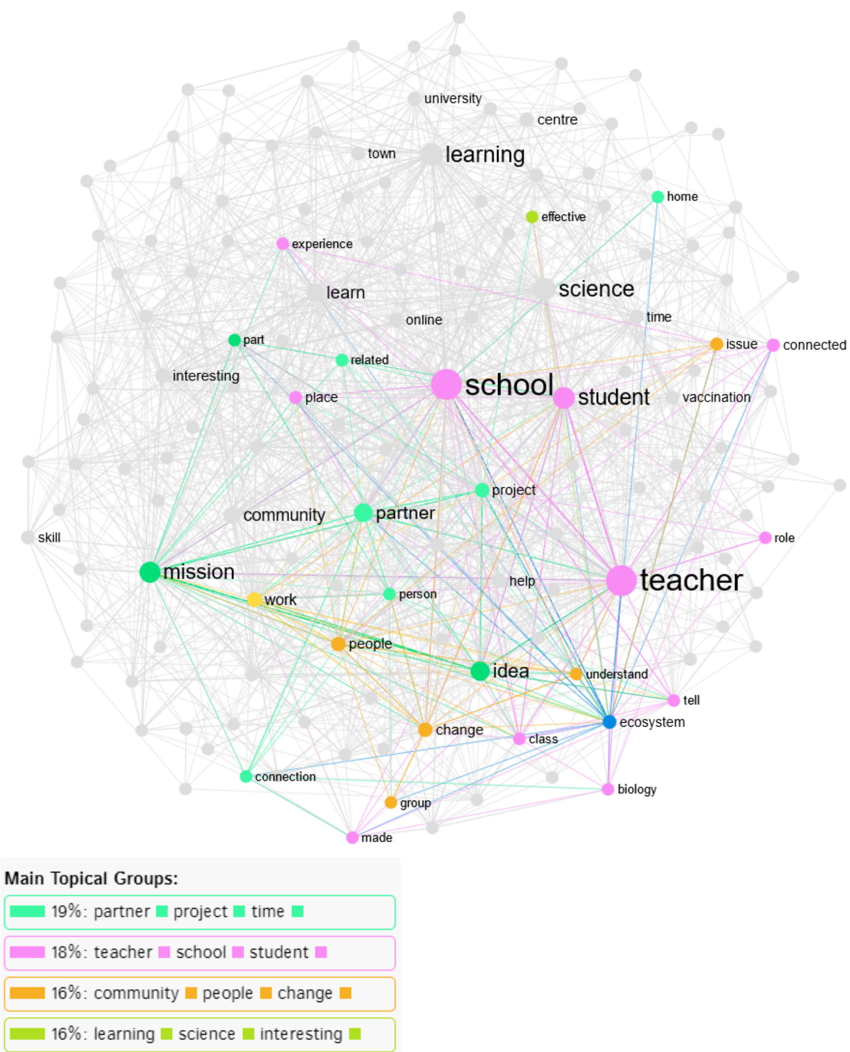

Figure 4.3 The main topical groups in the students' answers (source: infranodus.com)

Students

Four topical groups are prominent in students' answers (Figure 4.3). 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 realizing school's material and fulfilling the missions in the Ecosystem project" (PS2).

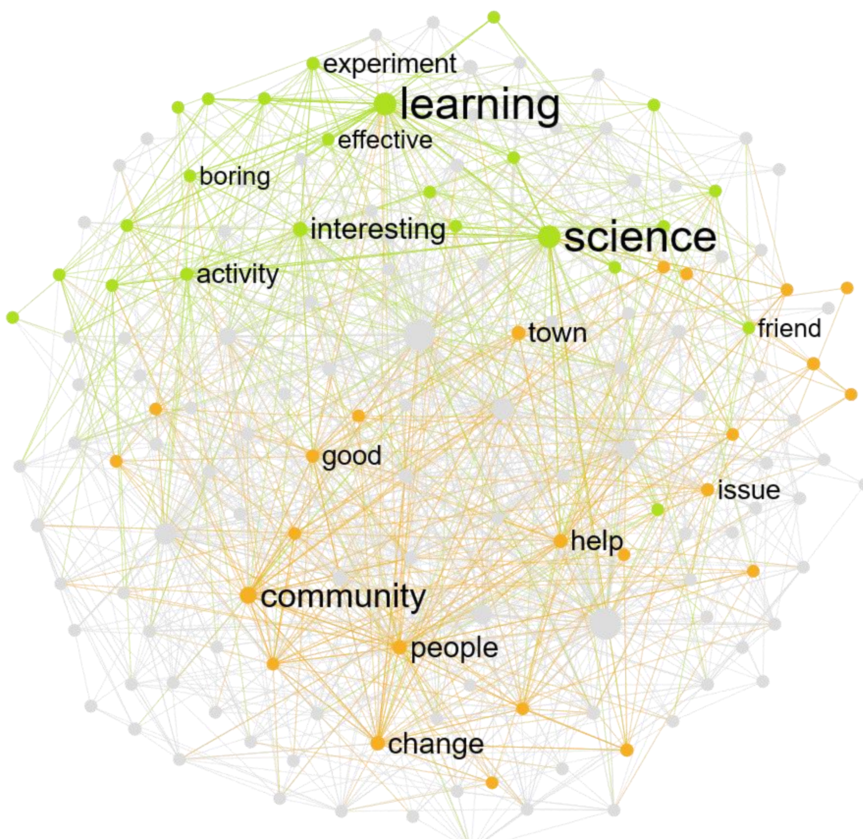

Figure 4.4 The structural gap in the students' interview data

There is a gap between the two topical groups of “learning, science and interesting” and “community people and change” (Figure 4.4). It seems from the data in general that the students did not 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 preliminary study they showed their awareness about the contribution to the community of the OSS missions.

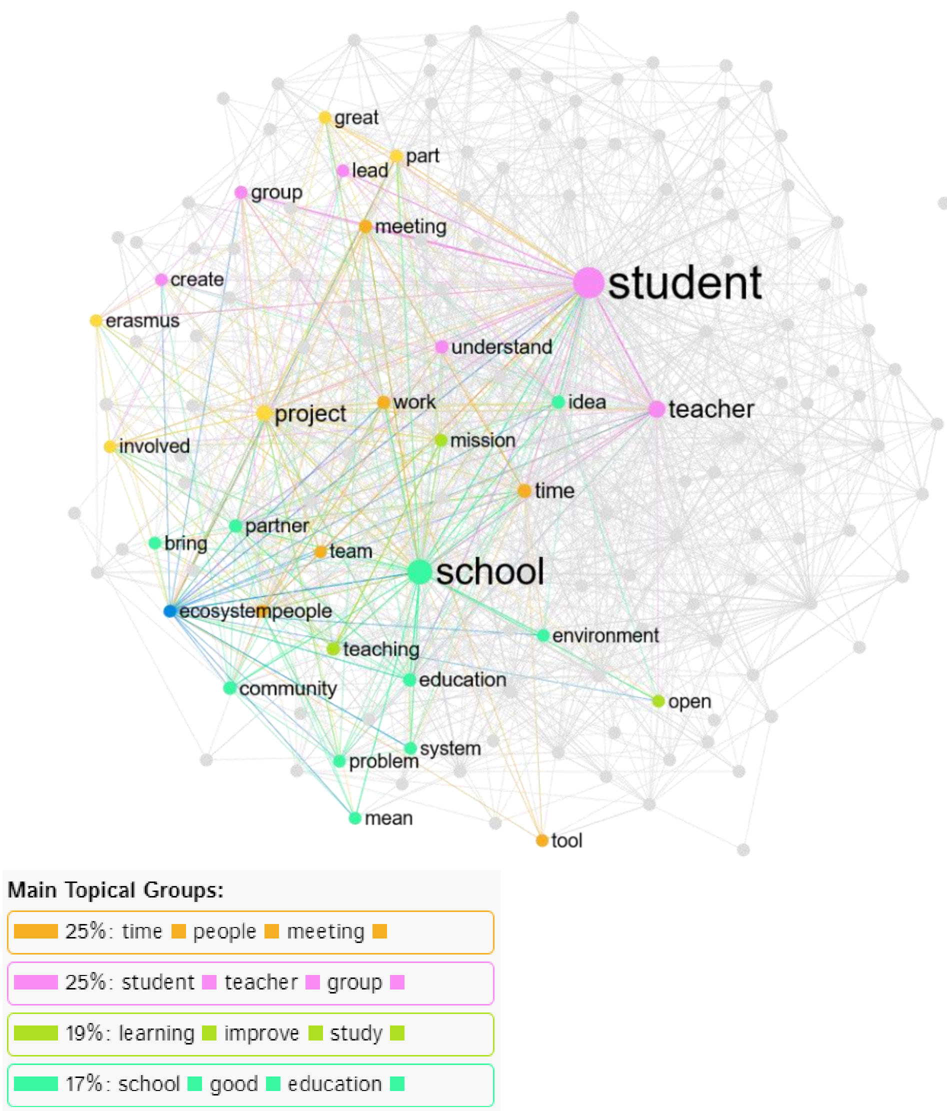

Figure 4.5 The main topical groups in the teachers’ answers (source: InfraNodus)

Teachers

Figure 4.5 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).

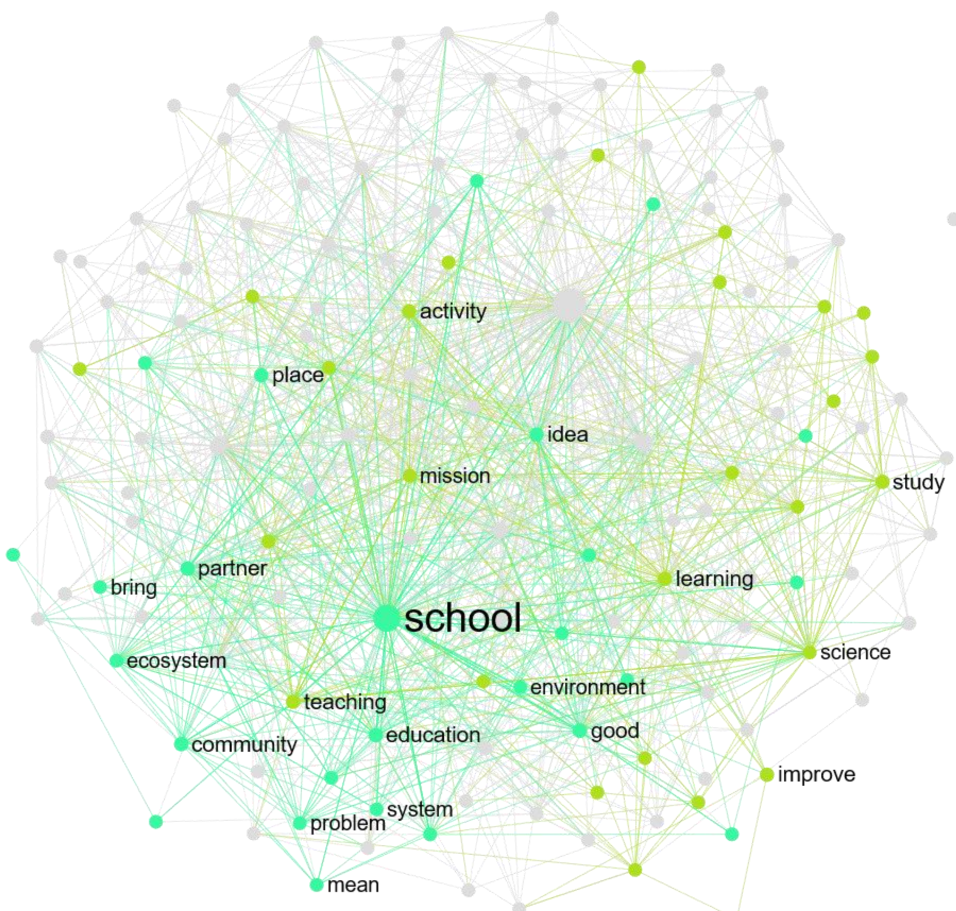

Figure 4.6 The structural gap in the teachers’ interview data

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 4.6). 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.

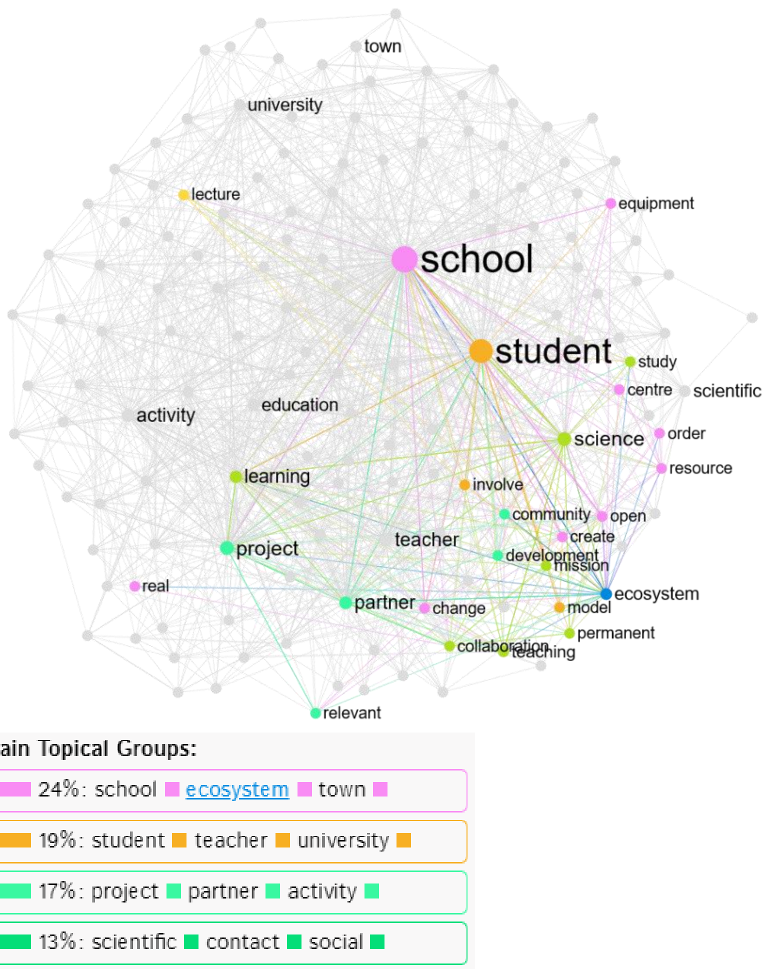

Figure 4.7 The main topical groups in the school administrators' answers (source: InfraNodus)

School administrators

The school administrators are aware of the central role of the school in the ecosystem and the local community (Figure 4.7). 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).

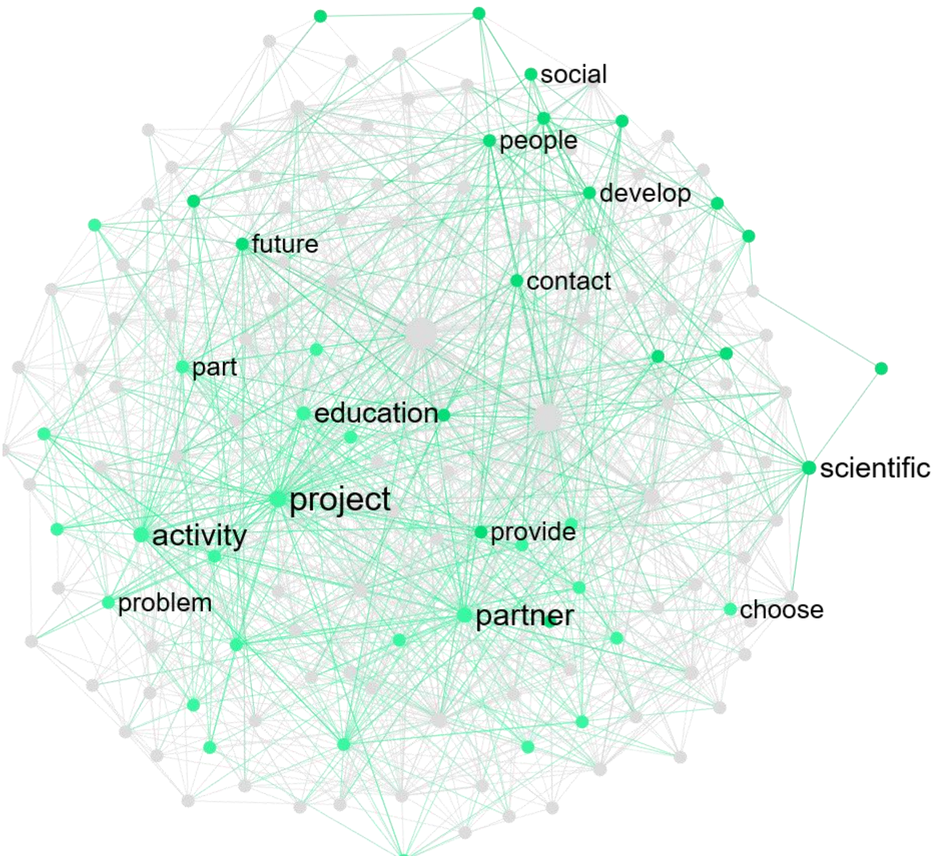

Figure 4.8 The structural gap in the school administrators' interview data

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 4.8). 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.

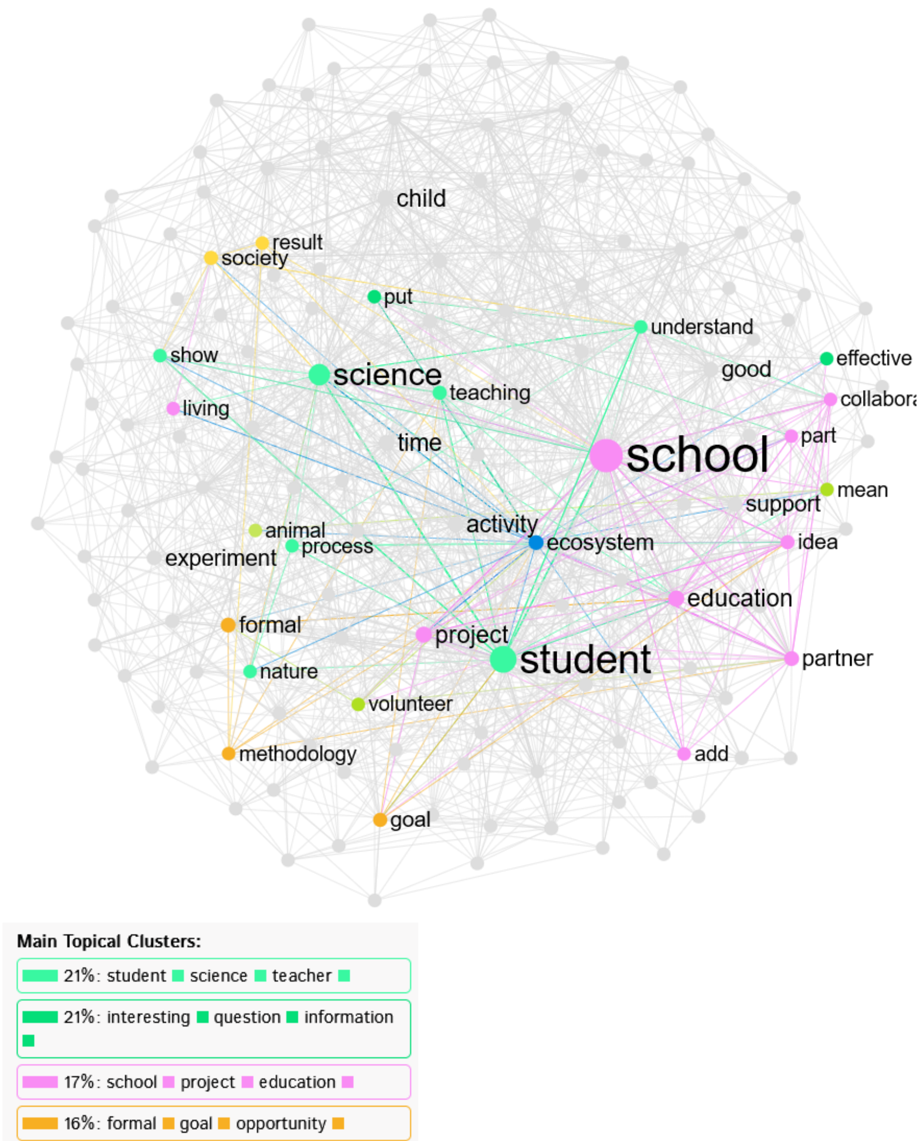

Figure 4.9 The main topical groups in the ecosystem partners' answers (source: InfraNodus)

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 4.9). 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.

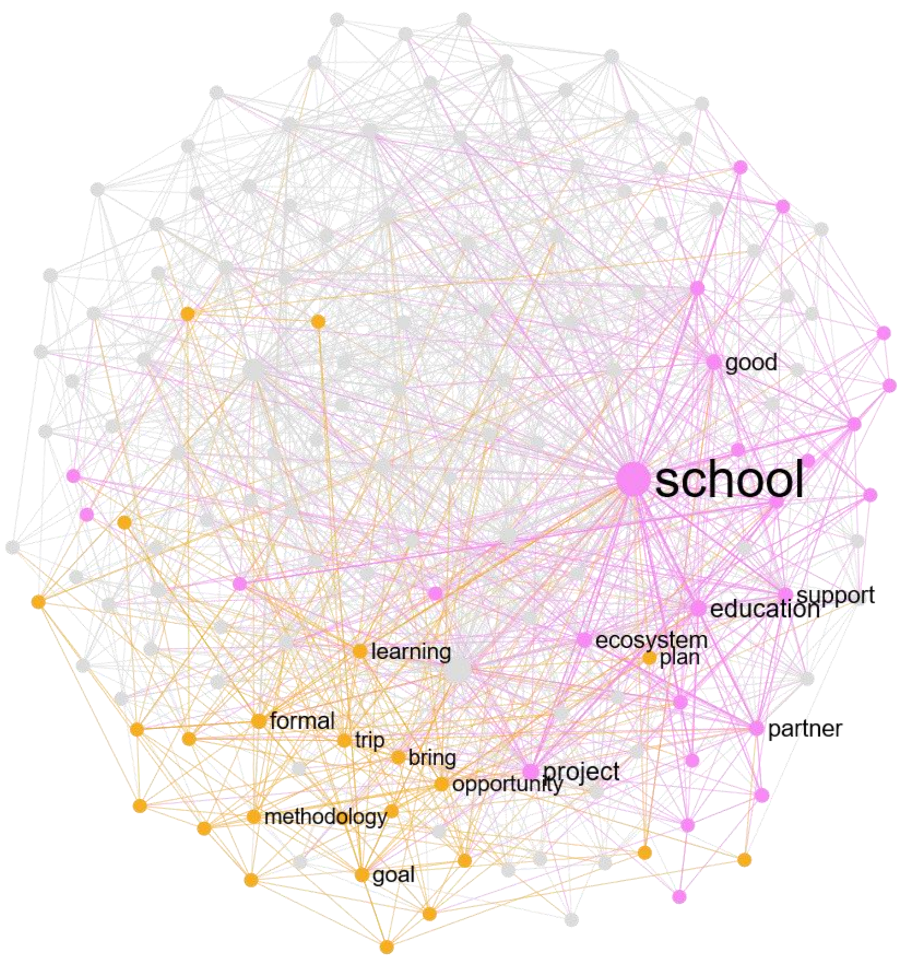

Figure 4.10 The structural gap in the ecosystem partners’ interview data

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 4.10). 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).

Conclusions and discussions

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 national policy of education out of the school campuses during the Pandemic, or 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. Collaboration between schools and external partners is key, with some ecosystems focusing on the school environment and others extending to the broader community. Despite challenges like adapting to new methods and the pandemic, Eco-OSS fosters student-centred learning, boosting motivation, engagement, and skill development, while also benefiting teachers.

The features of OSS ecosystems

Open science schooling activities are and must be designed to engage and re-engage students in science learning, as highlighted in the component of pedagogy in the EEE model (Mueller & Toutain, 2015). 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 in previous studies 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 (Gibson & Chase, 2002; Eshach & Fried, 2005; Potvin & Hasni, 2014). 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.

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 (Oakes et al., 2018). By becoming more involved in such activities, schools can help create OSS ecosystems that will benefit all members of their community.

Though it is still debatable that the use of social networks can help students to be motivated in their studies by providing them with a sense of connection to the larger world (Koranteng et al., 2019), social networks can still help students learn about local and global science missions in an engaging way (Höttecke & Allchin, 2020). 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.

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 (Owen et al., 2012). Open science schooling can help increase critical thinking skills among the students (Hikmawati et al., 2020). 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.

Recommendations

The OSS ecosystem should provide systematic guidance and sustainable opportunities/facilities for students to explore and practice 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 (Zulyusri et al., 2023). 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.