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Promoting sustainable practices through education: insights from the SAFE living lab initiative

Mariaelena Murphy[a]*, Robert Obenaus-Emler[a]

[a]Resources Innovation Center, Montanuniversität Leoben, Franz Josef-Strasse 18, 8700 Leoben, Austria

***Corresponding author: Mariaelena Murphy mariaelena.murphy@unileoben.ac.at**

Abstract

This paper explores the development of a Living Lab, Sustainable Agriculture and Forestry Explained (SAFE), initiative led by the Resources Innovation Center at the Montanuniversität Leoben, designed to strengthen the university's role in the EU Missions of adaptation to climate change and healthy soil. The SAFE initiative employs the Living Lab concept to create a dynamic, real-life setting where stakeholders from academia, industry, and the community collaborate to explore develop and implement sustainable agricultural and forestry practices. The paper details the strategic implementation, educational outreach, and collaborative efforts aimed at fostering these practices. It emphasises the importance of education in building a competitive Europe, linking the initiative to broader EU policies such as Horizon Europe and the European Green Deal. By engaging various target groups through participation and research and educational activities, the SAFE initiative aims to increase societal awareness and acceptance of sustainable technologies, ultimately contributing to the EU's goals of climate resilience and environmental sustainability.

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1. Introduction

In response to the pressing global challenges of climate change and environmental degradation, the European Union (EU) has launched a series of ambitious missions under the Horizon Europe framework [1]. These missions aim to tackle some of the most significant societal issues of our time, including climate resilience, soil health, and sustainable urban development [1–3]. Universities, as centres of research and innovation, play a crucial role in these efforts. They not only contribute through cutting-edge research but also engage in the practical implementation of sustainable solutions.

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Through the Resources Innovation Center, the Montanuniversität Leoben has taken a proactive approach to supporting the EU Missions of adaptation to climate change and healthy soil through its innovative initiative, the Living Lab 'Sustainable Agriculture and Forestry Explained (SAFE)'. The SAFE initiative embodies the concept of a living lab, an open innovation ecosystem that will bring together stakeholders from academia, industry, and the community to collaboratively develop, test, and implement new technologies and practices in real-life settings [4].

The Living Lab concept, central to the SAFE initiative, fosters a participatory and multi-disciplinary approach to innovation [5]. It emphasises user-centered research, where practical solutions are created and shared with society. This approach not only enhances the relevance and impact of research but also facilitates the adoption of sustainable practices by the wider community [6].

Education and community engagement are central to the SAFE initiative, aligning with the principles of engineering education 5.0 through integrating sustainable themes into university activities [7]. This educational focus also aligns with broader EU policies, such as the European Green Deal [3] and the EU Biodiversity Strategy [2], which emphasises the importance of knowledge dissemination and societal involvement in achieving environmental goals. Furthermore, SAFE fosters life-cycle learning and equips students with the necessary skills for Industry 4.0 and 5.0 [8]. This approach aids hands-on learning and collaboration between academia and industry, the SAFE initiative contributes to a competitive Europe, and also helps with societal acceptance of advanced technological solutions.

The linkage between SAFE and Engineering Education 5.0 is also relevant for ensuring societal acceptance of Industry 4.0 and emerging technologies. As students engage in life-cycle learning, they develop a deep understanding of the technological, economic, and environmental impacts of these innovations. This knowledge empowers them to become advocates for sustainable practices. The SAFE initiative's emphasis on practical, real-world applications of research helps bridge the gap between technological development and societal acceptance, ensuring that new technologies are not only innovative but also broadly accepted and integrated into society [9].

This paper explores the strategic implementation, educational outreach, and collaborative efforts of the SAFE initiative. It highlights the importance of education in building a competitive Europe and links the initiative to broader EU policies, Engineering education 5.0, and the global shift towards Industry 4.0 [10]. Through detailed descriptions of the SAFE initiative's objectives, methodology, and impact, this paper aims to demonstrate how living labs can serve as effective platforms for fostering sustainable practices and contributing to the EU's diverse missions [4].

1.1 Objectives of the SAFE Initiative

The SAFE initiative is designed with several key objectives that align with the broader goals of the five EU Missions, particularly 'Adaptation to Climate Change and Soil Deal for Europe' [11], Engineering Education 5.0, and the principles of Industry 4.0. These objectives aim to drive sustainable development, enhance research impact, and foster meaningful collaboration among various stakeholders.

By integrating practical, hands-on experiences with cutting-edge research, the initiative seeks to bridge the gap between academic knowledge and real-world application. Additionally, it strives to create a resilient and adaptable framework that can respond to emerging environmental challenges and technological advancements. The specific objectives of the SAFE initiative are as follows:

1.1.1 Promote sustainable agriculture and forestry practices

The primary objective of the SAFE initiative is to develop and promote sustainable agriculture and forestry practices. This involves creating innovative solutions that enhance the resilience of agricultural and forestry systems to climate change. The initiative focuses on practical applications such as the use of biochar in soil improvement and sustainable land management techniques [12]. By implementing these practices in real-world settings, SAFE aims to

demonstrate the viability and benefits of sustainable approaches, thereby encouraging their adoption by relevant stakeholders in wider society [13].

1.1.2 Enhance visibility and impact of research through community engagement

Enhancing the visibility and impact of research is a crucial objective of the SAFE initiative. By engaging directly with the community, the initiative seeks to bridge the gap between scientific research and societal needs. Activities such as workshops, educational programmes, and public demonstrations are designed to disseminate research findings and practical solutions to a broader audience. This engagement helps to raise awareness about the importance of sustainable practices and fosters a greater understanding of the scientific processes involved. Additionally, it ensures that the benefits of research are felt beyond the academic community, contributing to societal well-being and environmental sustainability [4].

1.1.3 Foster collaboration among academic, industry, and community stakeholders

The SAFE initiative places a strong emphasis on fostering collaboration among various stakeholders, including academic institutions, industry partners, and the community. This collaborative approach is essential for the development and implementation of innovative solutions that are both scientifically sound and practically applicable. By bringing together diverse perspectives and expertise, the initiative aims to create a synergistic environment where ideas can be shared, challenges can be addressed collectively, and new opportunities for innovation can be explored. This collaboration also supports the principles of Industry 4.0, which emphasizes the integration of digital technologies and practices in sustainable development [14].

Through these objectives, the SAFE initiative not only contributes to the applicable EU Missions of adaptation to climate change and healthy soil but also aligns with the goals of Engineering Education 5.0. By promoting sustainable practices, enhancing research impact through community engagement, and fostering collaboration, the initiative aims to create a sustainable and resilient future, supporting both local and global efforts towards environmental sustainability.

1.2 Methodology

The methodology section outlines the systematic approach employed in the SAFE Living Lab to achieve its objectives. It details the Living Lab concept, its application within the initiative, the importance of education, and the phased implementation and evaluation processes. This framework ensures that sustainable practices are developed, tested, and refined through participatory research and community engagement, aligning with EU policies and fostering collaboration among diverse stakeholders.

A Living Lab is an open innovation ecosystem situated in a real-life environment where stakeholders collaborate to create, validate, and test new technologies and solutions [5]. This concept encourages innovation through a user-cantered, multi-disciplinary approach, involving the active participation of end-users, researchers, industry partners, and community members. By focusing on real-world applications, Living Labs facilitate the co-creation of solutions that are both practical and relevant to societal needs.

Additionally, Living Labs serve as dynamic platforms for teaching and learning, providing the public with hands-on experience in understanding and applying new technologies. They bridge the gap between theoretical knowledge and practical implementation, fostering a deeper engagement with sustainable practices [4].

1.2.1 Integrating Stakeholder Engagement and Societal Learning in SAFE

The following sections explore the various applications of the Living Lab concept within the SAFE initiative. The SAFE initiative extends the Living Lab concept by actively involving stakeholders in the development of societal learning rather than focusing solely on fundamental research. This approach ensures that the knowledge and practices generated within the initiative are not only innovative but also accessible and applicable to the wider community.

Stakeholders, including local communities, educational institutions, and industry partners, are engaged in the process of societal learning. This includes participating in workshops, educational programmes, and public demonstrations, where they can both contribute to and benefit from the knowledge being shared. By emphasising the importance of community involvement in sustainable practices, SAFE fosters a culture of learning and adaptation that supports long-term societal resilience and environmental stewardship.

1.2.2 Creating a Dynamic Platform for Testing and Implementing Sustainable Agricultural and Forestry Practices

SAFE establishes a dynamic and interactive platform where innovative agricultural and forestry practices can be tested, refined, and implemented. Through real-life experimentation and demonstration projects, stakeholders have the opportunity to observe, evaluate, and contribute to the development of sustainable practices. This includes techniques such as the application of biochar and soil health improvement. This hands-on approach not only validates the effectiveness of these practices in real-world settings but also facilitates their adoption among a broader range of stakeholders, ensuring that these sustainable methods gain traction and are more widely implemented.

1.2.3 Importance of Education

Education is recognised as a cornerstone of the SAFE initiative, particularly in fostering a competitive Europe that is capable of addressing the challenges of sustainable development. The initiative integrates modern educational methods that emphasise experiential learning, critical thinking, and problem-solving. By equipping students with the necessary skills and knowledge, SAFE contributes to building a workforce that is prepared to meet the demands of Industry 4.0 and beyond, thereby enhancing Europe's competitiveness on the global stage [16].

1.2.4 Education as a Means to Educate Society

Beyond formal education, the SAFE initiative actively engages the broader community in its efforts to promote sustainable practices. This is accomplished through targeted educational programmes, workshops, and public outreach activities that are designed to increase awareness about environmental sustainability and the importance of adopting innovative agricultural and forestry practices. By extending educational efforts beyond the academic setting, SAFE helps to foster a deeper understanding and broader adoption of sustainable practices across society.

1.2.5 Link to EU Policies

The SAFE initiative is closely aligned with key EU policies, including Horizon Europe [1], the European Green Deal [3], and the EU Biodiversity Strategy [2]. By integrating these strategies into its educational and research activities, SAFE not only enhances the societal impact of its efforts but also ensures that its initiatives are aligned with and contribute to the EU's overarching goals of sustainability and climate resilience. This alignment underscores the policy relevance of the initiative, further reinforcing its role in advancing Europe's environmental and sustainability objectives.

1.2.6 Implementation Phases and Evaluation Criteria

The SAFE Living Lab's implementation follows a structured, phased approach, ensuring systematic development, testing, and broader community integration. Evaluation criteria, based on continuous feedback, are used to assess and refine practices, guaranteeing effectiveness and alignment with project **goals**.

1.2.7 Establishing a Structured Approach to Develop, Test, and Refine Sustainable Practices within the Living Lab Framework

The implementation of the SAFE initiative follows a structured approach that includes multiple phases: initial planning and stakeholder engagement, development of pilot projects, testing and refinement of practices, and large-scale implementation. This phased approach ensures that each step is carefully planned and executed, with continuous input from all stakeholders. This structured methodology is crucial for maintaining the initiative's focus and ensuring that the solutions developed are practical, effective, and scalable [5].

1.2.8 Continuous Assessment and Adaptation Based on Feedback from Participants and Stakeholders

To ensure the ongoing effectiveness and relevance of the practices implemented through the SAFE initiative, continuous assessment and adaptation are integral components of the process. Feedback from participants and stakeholders is systematically collected and analysed, allowing for regular improvements and adjustments to both the practices and the methodologies employed. This iterative process guarantees that the solutions developed remain robust, scalable, and well-aligned with the evolving needs of the community and industry partners.

1.2.9 Measures and Instruments to Achieve Implementation Goals

The implementation of the SAFE Living Lab's objectives is supported by a range of targeted measures and instruments. These tools, including workshops, hands-on activities, and collaborative projects, are crucial for ensuring effective sustainable development and community engagement. Continuous feedback and communication strategies help to refine these measures, ensuring they remain relevant and impactful.

1.2.9.1 Workshops

Workshops play a vital role in initiating new networks or strengthening existing ones, developing new concepts, and defining further measures. These workshops are utilised in a cascading manner, where content and action fields are selected based on research and teaching within the scientific community. Subsequently, action options and activities are developed with the involvement of all university groups and are implemented in subsequent workshops. This iterative approach incorporates feedback loops, which are essential for adapting and improving measures to ensure they meet the initiative’s goals [17].

1.2.9.2 Do-it Labs

The Do-it Lab approach, already implemented in university teaching, facilitates the direct involvement of students. Within this framework, measures and activities are developed for different target groups within the Do-it Labs and are subsequently implemented by students through teaching activities for pupils, public workshops, and/or events. This approach not only enriches the educational experience of students but also extends the initiative's reach into the broader community.

1.2.9.3 Events

Events are designed to convey content to a broader audience using a variety of methods. This includes demonstrations of research activities and participation in the setup and conduct of experiments. The contents of the relevant EU missions are integrated into teaching, with increased visibility achieved through topic-specific talks and lecture series. These events help to engage the public and enhance understanding of the initiative's objectives and the broader EU missions.

1.2.9.4 Educational Concepts

Educational concepts developed under the SAFE initiative make essential content related to the EU missions accessible to a wide audience, including schools and adult education programs. The Resources Innovation Centre (RIC) has gained extensive experience in education pedagogy and didactics through its numerous internationally

funded projects. This expertise, combined with the focus on EU missions, ensures that the educational concepts developed are robust and effective. To achieve maximum impact, these concepts are created based on modern teaching methods and are pre-tested with relevant stakeholders, allowing for improvements or adaptations through evaluation. This approach ensures that the educational materials are relevant, engaging, and capable of fostering a deep understanding of sustainability practices among diverse audiences [17].

1.2.9.5 Surveys and Polls

Surveys and polls are used to effectively gather information from different groups, which then serve as a basis for planning and implementing activities. These tools also provide an initial connection to the topic, generating additional interest and aiming to initiate mindset changes within the stakeholder groups. A feedback loop model is maintained to safeguard the content with regard to quality and relevance, ensuring that the materials and approaches remain responsive to the needs of the community [18].

1.2.9.6 Communication Instruments

Digital and print media offer valuable opportunities to reach additional groups, thereby broadening the dissemination of topics related to the Living Lab and the EU missions within society. Expert contributions are further utilised for discussions with specialists in interdisciplinary and transdisciplinary discourse. The initiative leverages established university communication channels and local media to enhance visibility, ensuring that the key messages reach a wide audience.

1.2.9.7 Videos

Essential content on the relevant EU missions and activities derived from the SAFE Living Lab is presented in various formats, including explanatory videos. These videos are created for both educational purposes and the general public, ensuring that complex topics are accessible and engaging. Additionally, expert videos created during talks and lectures given at events are recorded and made available digitally. This comprehensive video library allows for wide dissemination of knowledge, making it easier for a broad audience to understand and engage with the initiatives related to the EU missions. By providing these resources, the initiative enhances its educational outreach and ensures that valuable insights are shared widely.

1.2.9.8 External Networks

Thematic activities related to the applicable EU missions are emphasised within existing networks, and new networks are created to facilitate exchange with other expert groups explicitly pursuing topics and activities related to the EU missions. This network-building effort enhances collaboration and the sharing of best practices, contributing to the overall success and impact of the SAFE initiative.

Depending on resource availability and competencies, additional instruments may be implemented during execution. These could include targeted communication of action options through games or the artistic treatment of thematic content. Furthermore, innovative approaches such as virtual reality (VR) experiences and interactive simulations could be employed to immerse the public and stakeholders in the practical applications of sustainable practices.

Collaborations with local artists and cultural institutions could also be pursued to create engaging and thought-provoking exhibits that highlight the importance of sustainability and climate resilience. These additional tools would not only enhance the visibility and impact of the initiative but also foster a deeper emotional connection and understanding among diverse audiences. By leveraging a variety of creative and interactive methods, the initiative can effectively communicate its objectives and inspire broader societal engagement in sustainable practices.

2. Strategic implementation

The strategic implementation of the SAFE Living Lab involves meticulous planning and development to ensure the successful realisation of its objectives. This section outlines the key components and processes involved in establishing the Living Lab, leveraging its ideal location, and fostering collaboration with esteemed partners. By integrating sustainable practices and facilitating community engagement, the initiative aims to create a sustainable platform for research, education, and practical application of innovative solutions [11].

2.1 Site Selection and Setup of the SAFE Living Lab

The site for the SAFE Living Lab has been strategically chosen to be at the location of the new university's research centre on Hydrogen and Carbon. This site is ideal due to its vast area, which can support extensive research activities and public engagement. The presence of public paths and bicycle ways alongside the site ensures easy accessibility for community members, researchers, and stakeholders, facilitating greater participation and interaction.

Initial infrastructure development at this site will include the establishment of research plots, educational facilities, and demonstration areas equipped with the necessary tools and technologies to facilitate experimental and hands-on activities.

2.2 Key Components

The key components of the SAFE Living Lab are designed to support its mission of advancing sustainable practices and fostering environmental stewardship. These components include various research and educational initiatives that demonstrate practical applications of innovative solutions in real-world settings.

2.2.1 Future Use Forest

This component involves creating a forest designed to demonstrate sustainable forestry practices that are adapted to climate change. The Future Use Forest will serve as a living classroom where different forestry techniques, such as mixed-species planting and biochar application, are implemented and studied. These practices aim to enhance forest resilience, carbon sequestration, and biodiversity.

2.2.2 Raised Beds

Raised beds are established as hands-on activity areas for community engagement in sustainable agriculture. These beds will be used to teach and demonstrate techniques such as composting, crop rotation, and water-efficient irrigation. Participants will gain practical experience in managing these beds, fostering a direct connection with sustainable agricultural practices.

2.2.3 Research Projects on Demonstration Scale

Large-scale research projects will be implemented to showcase practical applications of innovative research findings. These projects will include pilot studies on soil health improvement, composting techniques, and the use of renewable energy in agricultural operations. The demonstration scale allows for data collection and analysis, providing valuable insights into the efficacy of these practices.

2.2.4 Biodiversity Measures

Initiatives to enhance biodiversity will be integral to the SAFE Living Lab. This includes planting a variety of flowering plants to attract pollinators where feasible, creating water bodies to support aquatic and semi-aquatic life, and establishing deadwood habitats for insects and fungi. These measures aim to create a rich and diverse ecosystem that supports overall environmental health.

2.2.5 Collaboration with Partners

Collaboration with esteemed partners such as the University of Natural Resources and Life Sciences (BOKU), the Federal Research Centre for Forests, and various industry partners is crucial for the success of the SAFE initiative.

These collaborations will bring together a wealth of expertise, resources, and technical know-how. Partners contribute to the development and implementation of research projects, provide access to advanced technologies, and support the dissemination of findings through their extensive networks.

Joint initiatives and co-funded projects enhance the scope and impact of the SAFE Living Lab, facilitating a multidisciplinary approach to addressing environmental challenges.

3. Challenges and Solutions

Implementing the SAFE initiative involves navigating several challenges that can impact its success. The initiative faces several potential barriers, including stakeholder engagement, resource allocation, and scalability. Effective stakeholder engagement requires overcoming scepticism and fostering trust among diverse groups. Strategies to mitigate this will include transparent communication, regular updates, and involving stakeholders early in the planning process.

Resource allocation challenges can be addressed by securing multi-source funding, optimising resource use, and leveraging existing infrastructure. Scalability issues are tackled by developing flexible models that can be adapted to different contexts and by documenting best practices for wider application. Engaging a broad range of stakeholders is crucial for the success of the SAFE initiative.

Techniques such as stakeholder mapping, regular consultation meetings, and participatory workshops will help in fostering inclusive collaboration. Ensuring active participation involves creating roles for stakeholders at every stage of the project, providing incentives for participation, and using interactive methods to engage diverse groups. Building a sense of ownership among stakeholders encourages sustained involvement and commitment to the initiative's goals [12].

Efficient resource management is essential for the sustainability of the SAFE initiative. This includes detailed planning, continuous monitoring, and adaptive management to respond to changing needs and conditions. Scaling up successful activities requires a strategic approach, including pilot testing, evaluation, and refinement before broader implementation.

Partnerships with industry, government, and other academic institutions can provide the necessary support and resources for expansion. Sharing success stories and demonstrating impact helps in attracting further investment and collaboration [13].

4. Conclusion

The SAFE initiative should significantly contribute to the EU Missions by promoting sustainable agriculture and forestry practices, enhancing research visibility, and fostering community engagement. Key achievements should include the development of practical solutions for climate resilience, the successful implementation of public participation, and the establishment of strong collaborative networks.

Living Labs have proven to be effective platforms for promoting sustainable practices. They facilitate the co-creation of solutions by involving diverse stakeholders in real-life settings, ensuring that the solutions are practical and widely accepted. The Living Lab approach enhances learning, innovation, and the adoption of sustainable practices by providing hands-on experiences and fostering community involvement.

Throughout the implementation of the SAFE initiative, the emphasis on education and community engagement will be a central focus. By integrating sustainable themes into university curricula and conducting workshops and outreach activities, the initiative aims to raise societal awareness and promote the acceptance of sustainable technologies.

This aligns with the principles of Engineering Education 5.0, which emphasises life-cycle learning and the continuous development of skills necessary for Industry 4.0. The initiative's strategic use of innovative educational methods will prepare students and community members to embrace and advocate for sustainable practices, thereby supporting the goal of a competitive Europe.

Moreover, the collaborative efforts with respected partners such as BOKU, the Federal Research Centre for Forests, and various industry partners will be crucial in expanding the scope and impact of the SAFE Living Lab. These partnerships will facilitate the sharing of expertise, resources, and technologies, thereby enhancing the research outcomes and their applicability.

The SAFE living lab highlights the importance of integrating sustainable practices with policy frameworks. Future research will explore new areas such as the integration of digital technologies in sustainable practices and the socio-economic impacts of environmental interventions. Cross-disciplinary collaborations will play a vital role in addressing complex sustainability challenges, with possible opportunities to partner with fields such as data science, social sciences, and engineering to help develop innovative solutions.

In conclusion, the SAFE initiative aims to further promote universities to leverage Living Labs to drive sustainable development and address pressing environmental challenges. The goal is to underscore the importance of education, community engagement, and collaboration in promoting sustainable practices.

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