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Is a Living Lab Also a Learning Lab?—Exploring Co-Creational Power of Young People in a Local Community Food Context

Mukti R. Chapagain * and **Bent Egberg Mikkelsen**

Department of Geosciences and Natural Resource Management, University of Copenhagen, 1165 København, Denmark; bemi@ign.ku.dk
* Correspondence: mrc@ign.ku.dk

Abstract: Living lab approaches are increasingly being explored and studied as means to address societal problems and develop viable solutions. The approach put emphasis on user participation as a way to co-create new technologies, products or services in an open and real-life environment. Against this background, we set out to ask to what extent a living lab can also be a learning lab. We used the concepts of Project-Based Learning and STEM teaching approaches as a theoretical framework to understand the potential of the Living Lab concept to create learning as well as solutions. This study applies a case study approach as a method for qualitative data collection. The case of the learning lab at "Læringshuset"—one of the schools involved in the SESAM program, was used as the case. The themes for the SESAM program were to create an understanding of the principles of sustainable food production and consumption using a scientific approach. The "Læringshuset" is a newly built school tailored to Project-Based Learning (PBL). In total, 12 rounds of interviews were carried out with three different types of informants who were involved in the SESAM program at Læringshuset: pupils (n = 8), teachers (n = 2) and mentors (n = 4). The data collected formed part of a larger data set that was collected as part of the SESAM evaluation in the 2021 and 2022 versions. This study concludes that the Living Lab format created around a school setting can serve multiple purposes: (i) it can be an important solution provider that acknowledges the value of solutions from young minds, and (ii) at the same time, it can be a learning lab in which multiple actors from the local community can engage in creating valuable solutions and learn from each other. Using the Living and Learning Lab is a good way to create both action and engagement and empowerment, and in particular, we find that it is well suited to create cross-community engagement around topics related to green food system transformation.

Keywords: Living Lab approach; project-based teaching; STEM teaching approach; food literacy

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1. Introduction

Living lab approaches are increasingly being explored and studied as means to address societal problems and develop viable solutions [1]. The Living Lab approach assumes a user-centric open innovation ecosystem that has the purpose of translating the results from the innovation process into practices and experimenting with potential solutions and future scenarios [2–4]. The approach put emphasis on user participation as a way to co-create new technologies, products or services in an open and real-life environment. The real-life environment is facilitated by the involvement of relevant actors as mentors/supporters for co-development, which is considered a Multi-Actor approach [2,3]. This user-centric way of creating innovation is particularly relevant when it comes to complex problems and challenges that require the active involvement of users in order to define their needs. Furthermore, the approach is also relevant for challenges that have no easy or straightforward solutions—the type of problems that are often referred to as "wicked problems". Such problems require the active involvement of multiple stakeholders in order to extract the necessary and different types of knowledge and expertise. It also requires the alignment of the different expectations of this multitude of actors. Addressing such challenges relies on the input of knowledge, cooperative efforts and acceptance from involved stakeholders, and the format of the Living Lab has, over the past decade, developed and claims to have the potential to create solutions with broad appeal and acceptance. The transformation of the food system in the wake of the climate and biodiversity crises is one such challenge. It is urgently called for by various policy documents and research papers in the wake of the climate crisis [5–8]. Such food system transformation involves a long range of actors along the food value chain, and it involves both production and consumption as key elements [9–11].

The Living Lab approach aims to create an ecosystem that—inspired by different future scenarios—can turn the result of the innovation process into potential solutions using an experimental approach [2,3,12]. Some of the important features of the Living Lab approach include user participation and the broad engagement of different actors to explore potential solutions [2]. This kind of Multi-Actor approach permeates recent policy documents on innovation and climate adaption and includes the capacity to co-create new technologies, products or services in an open and real-life experimental environment [3]. As such, the Living Lab approach holds the potential to make important contributions to the food system transformation that is needed in collaboration with different actors in the food system [12]. It is therefore not surprising that much policy and research effort has been mobilized to examine the full potential of Living Labs in a food context.

Schools are increasingly seen as a game changer when it comes to addressing food system transformation. As such, providing food-related knowledge and skills to young people, which is the concept of food literacy, has gained much attention in recent years. The concept is highly contextual, and its components consist of planning, selecting, preparing, and consuming food and understanding the impact of food choices on health, the environment and the economy. It emphasizes both the acquisition of critical knowledge (information and understanding) and functional knowledge (skills, abilities and choices) [13]. Some of the emerging skills and knowledge are related to healthy food choices, preventing and reducing food waste, and so on [14,15].

According to studies made by EIT Food and Food Tank [6,9], important components of young people's expectations in the domain of future food systems can be summarized as follows: to be part of the solution; to have better labeling on products; to have better advice on the link between diet and mental health; clearer overall health and nutrition advice and information; increased access to safe and nutritious food; and improved food system resilience, alongside a healthier and more sustainable production and consumption regime. Young people are increasingly worried about issues such as climate change, food sustainability, and other issues in the food domain [7,16,17]. Furthermore, young people's engagement with food systems is categorized into four domains: biophysical, economic, cultural and social [10].

Students tend to be motivated to learn because they use scientific problem-solving skills in their future career development [18]. Studies suggest that project-based and STEM teaching approaches could have a positive impact on students [19–21]. However, one component of Project-Based Learning seems to be missing in the STEM teaching format [20], since in order to facilitate project-based and STEM teaching approaches, schools need to establish external collaboration. This obviously requires extra effort, and at the same time, it can be challenging [22–25].

Research work in the scope of the Living Lab domain so far has mainly focused on solutions in a grown-up and adult context. Less work has been performed trying to look at the learning perspectives of such labs in the context of young people in school environments or to combine the two perspectives. It is therefore highly relevant to explore to what extent the idea of a living lab can be used as a transformative power as part of the current efforts to rethink food at school. Against this background, we set out to ask to what extent a living lab can also be a learning lab. In other words, we set out to explore and examine the question of whether co-creation can be seen from an extended perspective where it leads to multiple outcomes where innovation, community cooperation, mentoring, the creation of solutions, and learning for young people go hand in hand. We use the innovation and learning needs evoked by the call for food systems transformation and the increased interest in using the school as the frame for exploring this.

A review of state-of-the-art research on the living lab approach and school outreach activities clearly shows that pupils' engagement in the learning process increases the possibility of learning about contemporary issues [22,26–28]. Implementing the concept of living labs in a school environment that is highly structured, organized and focused on being able to deliver what is called for in the school curriculum seems to be a challenging task [22]. In addition, food, food systems and innovation topics are not high on the agenda in an average elementary school. Outreach to the local community needed significant coordination with various actors and expertise in multiple subjects. Maintaining the interest of various actors in the local community while creating a learning space is one of the challenges [29]. We developed a protocol that was able to handle these challenges and set out to investigate the three main dimensions of the living lab approach: user involvement for co-creation, together with Multi-Actor engagement, and the real-life environment setting. To be able to extend the reach of the Living Lab approach to learning goals—to act as a Learning Lab—these three main dimensions have to support the learning goals. We asked the following research question:

"How can the elements of the Living Lab approach in the context of the food system transformation be used as a shared learning facility for young people and local food systems actors?"

We subsequently broke the question into three sub-questions:

1. **How can young people's voices be taken into account in such a Living Labs approach?** The living lab concept itself promotes the idea of user engagement for co-creation. However, making young people curious about contemporary societal issues and engaging them in finding solutions is an issue.
2. **How can outreach to the local community be applied to create engagement across different actor groups?** Engagement across various actor groups needs a certain strategic plan, and it might be difficult to maintain within-school outreach to local community programs.
3. **How can the school's environment and its learning opportunities be taken advantage of?** The school environment itself reflects the formal space of learning, but how to utilize it for young people's engagement in an open learning space.

The main purpose of these research questions is to explore to what extent schools and the surrounding local food community can play a role as co-creational spaces for both a meeting place for multiple actors and a learning opportunity for young people, families, teachers and other actors in the local community.

2. Conceptual Framework

We examined the learning potentials of the living lab approach within the context of the SESAM (Sense, Science & the Magics of Food) program. This study builds on several theoretical and conceptual positions that will be detailed in the following section: Problem- or Project-Based Learning (PBL), the Living Lab approach, the SESAM program and the STEM teaching approach.

2.1. Living Lab Approach

The Living Lab approach is a user-centric open innovation ecosystem that addresses a challenge or a set of challenges by ideating, developing and experimenting with potential solutions under the assumption of different future scenarios [2–4]. Three main features of the living lab approach include the following: user participation for co-creation; broad engagement of different actors—the Multi-Actor approach; and the capacity to co-create new technologies, products or services in an open and real-life environment [3]. The living lab approach can follow either open innovation or a user innovation pathway. The open innovation pathway follows the exploration, exploitation and retention of ideas in order to develop innovative solutions [4]. Likewise, user innovation follows user involvement in the co-definition and co-creation of technology, products and services [4].

The Living Lab approach entails the participation of four key actors: enablers, providers, users and utilizers [3]. The enablers play a crucial role in make all this possible by providing physical space, learning context and facilitating co-creation. The providers contribute knowledge and expertise, as well as innovation and support in their capacity as mentors. The users actively engage in living labs for co-creation and co-development. To that end, relevant industry actors who will participate as technology experts can be considered utilizers that will also benefit from the result of the innovation. As such, user involvement in co-creation is a key element in the Living Lab approach, together with the Multi-Actor space [2].

Applying the Living Lab format in a school setting means that pupils should play a vital role in the co-creation and requires the teacher to act as a facilitator. Multiple actors can be mobilized and involved as mentors to help pupils in the co-creation process [25]. Implementing the Living Lab in the educational space of the school tends to transform the learning approach to become more open-education oriented and open to collaboration with the local community and society [22]. The food system is a complex web of activities involving the production, processing, transport and consumption of food. This allows Living Lab actors that are driven by an interest in food systems transformation in a learning context to choose from a wide range of themes and expertise that they belong to, such as food waste management, cultures and traditions of food, carbon footprints of the food system, agriculture, physiology of taste, packaging, local circulation of food, health issues, economy and aesthetics [23,25].

2.2. Problem- or Project-Based Learning (PBL)

Different concepts such as Inquiry-Based Learning (IBL), Challenge-Based Learning (CBL) and Problem-Based Learning (PBL) are being used for "hands-on activities" type of learning practices where students become actively engaged to work with a real-life challenge and teachers are here acting as facilitators of the process [21]. In our study, we use the term Project-Based Learning (PBL) since we find that this concept best underlines the goal-orientedness of the learning processes.

PBL is considered a student-centered pedagogical method in which the student leads the learning process, whereas the teacher plays the role of facilitator to enhance students' creativity, provoke students' interest, and develop critical thinking and management skills. It is believed that students gain comprehensive knowledge through active exploration of real-world challenges and problems, with the opportunity to integrate knowledge with real-world experiences. The PBL approach can enable students' learning abilities, stimulate their motivation to learn, and facilitate the implementation of their capabilities. PBL has emerged as a preferred pedagogical method on various occasions (about learning) due to its potential to influence students' behavioral, cognitive and emotional engagement [19,21,30].

The most important feature that represents PBL is collaborative group work, where students are asked to work together, share ideas, and organize and manage their tasks [31,32]. However, the prime issue is how to engage young people in such issues as climate change, the future food system, and sustainable, healthy food consumption topics that are deeply related to our societal challenges and need collective efforts. A review by Corner et al. [5] highlights the need to involve young people when it comes to engaging other youth more effectively with topics, such as the climate change For effective engagement of young people in contemporary issues, they need to be properly informed and backed by facts, and peer networks and social media can be very effective [5].

2.3. The STEM Teaching Approach

STEM refers to an educational approach combining the fields of Science, Technology, Engineering and Mathematics (STEM). So it is able to integrate multiple disciplines, train students to use cross-disciplinary knowledge to solve problems, and promote a learn-by-doing approach. The approach aims to foster inquiring minds, logical reasoning and collaboration skills. The approach can also foster students' participation in real-world projects with real-world consequences [20].

Several attempts and efforts have been made at schools in many countries to upgrade the role of science-based teaching and Inquiry-Based Learning, such as the STEM teaching approach [33,34]. This kind of teaching approach seems to be effective in both—formal and informal teaching. For instance, science subjects such as chemistry can also be taught beyond the book in an open, activity-based, non-formal environment that inspires passion and curiosity [35]. The STEM approach opens the doors for active collaboration among teachers, scholars, scientists and industry, as well as new experiences for students. Furthermore, collecting and implementing different practical scenarios from a variety of application areas can increase the possibility for STEM teachers to design, plan and implement appropriate active learning scenarios in their own classes.

Lately, the use of digital technologies and STEM teaching principles have come into focus. The STEM principle embraces Creativity, Collaboration, Critical Thinking and Communication and incorporates project-based learning to address the various needs of learners and foster a love of learning [33]. Recently, Danish schools have increased their interest in upgrading STEM subjects through the development of new didactic approaches to teaching and the development of transversal skills such as digitalization, critical thinking, collaboration, design thinking and Project-Based Learning. Using design and science learning in relation to food has received increased attention over the past few years [36,37].

2.4. SESAM Program—Use Case of the Learning Lab

To examine in detail our assumptions that the Living Lab has both the potential to create food literacy and to generate valuable solutions to food system challenges, we used the SESAM program as a methodological foundation. This program has been developing over the last three years and is already using PBL and STEM teaching approaches to facilitate scientific and digital insights for young people about food topics in the school environment. The SESAM program is part of the European Researchers Night (ERN) program, a Europe-wide public event that brings researchers closer to the general public. In Denmark, we have thematized the ERN to be purely about food system change in a school environment context. During the events, researchers will meet the public with various citizen-oriented hands-on experiments, shows, games, exhibitions and digital activities. These activities aim to demonstrate the diversity of science and its impact on citizens' daily lives, stimulating interest in research careers—particularly among young people. Furthermore, the European Researchers Night events, such as the SESAM program, also aim to facilitate the understanding of research, science and innovation among children, young people and families through entertainment [38].

The SESAM program aims to demonstrate how scientific and digital insight among young people at school can contribute to solving some of the most urgent and complex sustainability challenges. The focus of the SESAM program was centered on fostering awareness and understanding around the principles of sustainable food production and consumption. The program uses digital and scientific insight as the foundation for creating learning and solutions to promote the transformation of green food systems. The program has been running for three consecutive years in close cooperation with schools. The program unfolds over 3 months over the summer period and consists of preparation phases and an execution phase. The program uses the interplay between the city's green transformation and food production/consumption to illustrate the role of science in society. Through the SESAM event and its preparation, young people will also learn more about careers in science and research.

The program focuses on particular goals of the SDGs (Sustainable Development Goals): 2 (no hunger), 3 (health), 4 (education), 7 (energy), 11 (cities), 12 (consumption/production), 13 (climate action), 14 (sea) and 15 (land). The program included examples of both marine and land-based food and protein resources—and both in cultivated and wild forms. The implication of the program is that it uses specific "installations", mock-ups, and learning tools (please refer to Table 1), including workshops and exhibitions, that all illustrate what research and scientific solutions can bring to citizens' lives. These themes of the program were reflected in the concept of Planet Pantry—the challenge of feeding a hungry world in a sustainable way and with maximal uptake of research. More detail on the SESAM program will be available later in the method chapter.

Here is a brief overview of SESAM tools that have been used at various events.

Table 1. SESAM tools for science and research communication to citizens.

Tools and Abbreviations	Definition
Science Workshop (SW)	A functional demonstration, installation, station, or mock-up that illustrates a research set-up
SofaTalk (ST)	A scheduled, moderated and seated talk about a research or innovation topic. Can be on the stage or broadcasted from a remote stage using video conferencing tools
Street and Citizen Science Experiment (SCE)	A citizen science type of research set-up where our guests engage voluntarily and are informed in a behavioral experiment arranged by researchers
EU Corner (EC)	A booth or counter-like type of service manned by a researcher or expert and offering handouts, for instance, about EU research and vis-à-vis the MSCA presentation stage
Science Show (SSH)	A scheduled show on a stage moderated by a young researcher

The table above (Table 1) shows an overview of the learning tools that have been used in the SESAM program. These learning tools aim to provide learning space for various target groups, such as pupils, citizens and early-career researchers. A citizen-driven bottom-up approach in order to communicate science and the involvement of early-career researchers in order to create researcher–pupil interactivity were considered.

3. Methods—Case Study Design

This study applies a case study approach as a research method to explore the potential of the Living Lab concept in the context of learning for involved actors. A case study is a research approach used to generate an in-depth, multi-faceted understanding of a complex issue in its real-life context [39,40]. This study was designed to explore a single case of a learning lab using the principles of action-based research methods, in which the researchers actively engage with various actors to identify and address real-world issues through practical actions and reflection. The actor groups we have engaged in the case are; mentors, local school representatives, teachers, the headmaster and pupils. The action research method allows us to learn through action and improvise the activities within the case while doing the research. This also means the data was collected along with the development of the intervention. The idea of the living lab crystallized along the way in the interactions between researchers, mentors, students and teachers. As such, the data collection will be mainly qualitative in nature, in the form of interviews.

For this case study, we used the case of "Læringshuset" to create and follow an emerging Living Lab since the thesis school was already engaged in the SESAM program.

3.1. Case Description—SESAM Learning Lab at Læringshuset

The "Læringshuset"—a newly built school that was tailored to Project-Based Learning (PBL). The co-creation activities are part of the PBL concept of the school (Læringshuset—Danish for "Learning House"), in which the learning lab plays a very important role.

The SESAM learning lab has been created as part of the close cooperation between the university and the school as one way to strengthen "science-to-school" cooperation. From the university perspective, the cooperation for the learning lab concept is partly to serve as the foundation for data collection and interventions in the SESAM-2030 program. The SESAM-2030 is the 2022–2023 version of the SESAM program, which aims to create an understanding of research and science and uses the need for green urban food system transformation as the science case. From the school perspective, the lab has been developed for Project-Based Learning (PBL), and the school's strategy includes participating in projects related to the development of better teaching and projects related to the field of technology understanding (a recently introduced school subject evolving around the teaching of computational thinking).

The SESAM learning lab relies on using mentoring as part of the co-creation process with the idea of designing, creating, building and constructing physical learning tools. As part of these projects, the school uses a mentor corps where representatives from small and large companies as well as academia are brought in to assist the students in their solution development. Researchers, mentors and topics from a broad range of sciences and disciplines, such as agriculture, landscaping, nature-based education, horticulture, urban planning, geography, nutrition and food studies, sensory and consumer science, and digital and data science, have been brought. The goal was to illustrate that more sustainable use of nature, as well as sustainable food production and consumption, depend on scientific insight from a broad range of disciplines. In addition, the school has a good working relationship with local retail stores about food waste and incorporates this into its teaching about food waste.

The project activities fall into two major categories: preparation/awareness raising and execution. Preparation takes place "backstage" with teachers and the SESAM researchers in the weeks up until the summer break and "frontstage" over six summer weeks after the summer break (with teachers and pupils). Through the preparation at school in the months before and after the summer break, we install, prepare, and refine each of the physical installations, workshops, mock-ups, demos, etc. that will form an important part of the foundation for the final events. Simultaneously, we prepare the shows and talks. Additionally, an important part of the pre-summer break backstage activities is to set the overall framework for the school and agree on the didactical foundation of the post-summer break activities. During this period, we bring in mentors and academic scholars for two purposes: to solve technical challenges and to create interaction between researchers and pupils.

3.2. Data Collection and Ethical Considerations

Qualitative data were collected during the implementation process of the SESAM learning lab. We used the principles of action research, in which a research case is developed in cooperation between researcher and practitioner and data are collected as an integral part of the development process. In total, 12 rounds of interviews were carried out with three different types of informants who are involved in the SESAM living lab. Pupils (n = 8), teachers (n = 2) and mentors (n = 4) are all affiliated with the case study school. The data formed part of a larger data set that was collected as part of the SESAM evaluation in the 2021 and 2022 versions.

For all adults (mentors and teachers), the data was collected directly by the researchers involved in the study. For all interviews with children, we used graduate students that were affiliated with the researchers' university as interns from three different universities. They worked with the research team in three different groups according to an agreed-upon protocol. For all students, a data handling agreement was made. The overall aim of the student projects was to understand the didactic principles guiding the implementation of the SESAM program. According to the agreement and the guidelines from their different universities, students are themselves responsible for being in compliance with GDPR and good research practices. The data handling agreement included the responsibility to keep all data in a protected data space. In the agreement, it was specified that data from minors could only be collected with permission from the school.

The school maintained, as part of its overall administrative system, a service in which permissions for minors to participate in research were governed by the school. The school informed all parents using the Danish Public School standard communication portal—Aula—about the purpose of the study (the SESAM ½ page handout) and the purpose of the data collection. The school maintained a positive list of students that could be enrolled, and data collectors used this list to make sure that only students that were not restricted from participating in interviews became part of the collection. For the GDPR set of rules, there were found to be no issues.

For access to data from adults, we used the SESAM half-page handout to make sure that the interviewees were informed about the purpose of the study. For the overall right of the university to collect data that is in the interest of the public—the common good—we based our study on the so-called "University Clause" that is part of the DK Protection Act. All interviews were recorded, transcribed verbatim and cleaned up subsequently. After cleaning up the transcribed interviews, all names were changed in order to secure anonymity.

3.3. Data Analysis

The study was carried out through qualitative analysis of the textual data from interview transcripts [39,40]. The strategy of the analysis was based on the principles of *hermeneutic analysis*, a special type of content analysis where the researcher tries to "interpret" the subjective meaning of a given text within its socio-historic context. As such, the researcher needs to make an interpretation of the content in relation to the context [39]. During the analysis, we should continually iterate between a singular interpretation of the text (the part) and a holistic understanding of the context (the whole) to develop a fuller understanding of the interviewee's response [39,40]. The unit of analysis will be pupils and their learning possibilities.

The data were analyzed based on various themes related to the learning lab concept. We used a deductive thematic approach and categorized the results of the interviews into three different categories, which are foundations to the learning lab concept and also our research sub-questions, such as: (1) pupil-driven exploration and project-based work in order to facilitate learning; (2) engagement of various outside actors as mentors that create learning space; and (3) project-based teaching that could familiarize students with real-life societal challenges.

4. Results and Analysis

As stated in the data analysis methods section, we grouped the findings under three main themes that, together, make up an overall patchwork of a living lab. Each theme was further broken down, and results are presented for each theme under a number of subheadings that each represent a significant finding.

4.1. Pupil-Driven Exploration and Project-Based Work That Facilitates Learning

An important part of the lessons learned in developing the project revolves around the idea of pupils' self-exploration of food themes under the umbrella of PBL. We find in the following several examples of ways in which the learning evolved in a project-based manner where students explored food systems-related issues that at the same time contributed to creating a sense of a living lab.

4.1.1. Self Exploration—A DYI (Do-Yourself-In) Approach That Stimulates Self-Learning

Science thinking was an important part of the project activities, and the planning for learning goals was closely related to the application of science principles. The scientific thinking added to creating a sense of need for a lab approach with an experimental approach that was appreciated by some students. Furthermore, students liked the independent, experimental approach and the fact that the SESAM program offered a flexible framework within which they were able to operate. The statements below show that the pupils liked both the co-determination element and teamwork that were part of the program. As expressed by pupils, teachers and mentors:

> "[...] The course is fun, and it is fun to make jams where you can determine the taste yourself" it's a kinda science-up the teaching."—Marta, pupil

> "She explains how she thinks that what they are doing right now has probably been the most fun. Both because they are allowed to experiment, but also because they themselves have chosen groups."—Carl, mentor

As statements have expressed, engaging with the group in an experimental manner is enjoyable, thereby greatly supporting the learning process. It further proved that the science-up teaching approach can facilitate a more "fun" way of learning. It quite soon became clear that project-based teaching seemed to help promote the students' motivation for self-experimentation and exploration. It also contributed to the development of a sense of autonomy among students and an interest in trying out new approaches to learning themselves. In addition, we found that learning to understand that in a playful way and at an early age was considered a clear advantage. As the following statements from a pupil and one of the teachers involved in the Microbit undertaking expressed:

> "I don't start asking the teacher, I try it out myself. I might be asking classmates or try to look it up on YouTube first up, Then I might consider asking the teacher."—Emil, pupil

> "We've used it a lot to train the children, this is a fantastic project to train the children to work independently, to help each other. They are very happy to learn this at an early age. It's making it SO much easier when they come up in the larger classes and they're really good at it."—Tina, teacher

Developing this student-driven autonomous approach gradually shifted the focus towards new learning and insight into the interrelationship between experiments, hypothesis building, and project organizing and solutions. We learned that working independently but still in a social manner is one of the positive outcomes. Although the teachers pointed out that the preparation for this kind of technology-assisted teaching requires time and concentration, it was seen that the pupils quite soon became able to assist each other in their understanding of how to work with these technologies.

4.1.2. Exploring to Design Technological Solutions That Facilitate Team Work, Innovation and Design Thinking

One of the important learning insights from the program was that the learning tools seemed to become more real, imaginable and virtually tangible when students started building cardboard models and prototypes. This became particularly clear when we added the digital components to the program.

> "We're working on prototypes in a lot of different ways. We have used strawberries, we have used tomatoes, and we have also drawn both computer and hand, and try to make 2D drawings about 3D drawings, for example."—Tina, teacher

In some cases, the physical models were supplemented with computer-assisted design, where students started drawing prototypes in 2D with a pen and pencil and later also 3D models, which stimulated design thinking in order to come up with the proper solution. In some of the activities, we learned that solutions and ideas do not have to be very complicated; it could just be a matter of combining existing things in order to create new value. An example was seen in the part of the activities that were related to exploring new types of smart bar codes, data-drivenness and app tech in creating applications to reduce food waste.

> " . . . . . . it was a bit the same as when you were able to put the barcodes and the app together. Because, it's a bit like that. It's a bit new since there was no app that both has a barcode scanner and is an app, so it's a bit like this: Now that they've put these two things together—it can help with something new."—Maria, pupil

This example illustrates that pupils tend to regard innovation as just an improved version of an existing solution, which they find relevant and useful. It also gives pupils some kind of understanding of both the importance of the problem and the value of their solution.

Some of the insights that developed during the project were the idea of not only building competence on various topics but also creating empowerment, for instance, by promoting food literacy. The food waste theme was consistently integrated into various school activities and extensively connected to technology in a lab-oriented approach to highlight technological significance. Some of the statements that were phrased:

> "This has certainly affected them positively. They have acquired a lot of food waste reduction competences within and about practices for reducing food waste."—Kirstine, teacher

> "They have also learned a lot of things about how we can use different technologies together to get a general understanding, but also about tools to reduce food waste and assist the general citizen."—Kirstine, teacher

These statements show that pupils tend to go beyond learning about food waste themselves and facilitate other people's learning. It certainly shows that pupils feel ownership over their solution and show interest in motivating other people as well when they are part of the co-creators of the concept.

4.1.3. Understanding Cutting-Edge Technology through Co-creation and Mentoring

An important part of the SESAM program is the inclusion of digital components to introduce necessary contemporary technology to young people. We experienced that involving young people as co-creators of mock-ups has the potential to be a powerful tool when it comes to illustrating what innovation, technology and digitalization can do for a more sustainable food and agricultural system. We also saw soon that the learning that spread from the interactions between students, teachers and mentors could be understood as something resembling a living lab. This became particularly apparent when day-to-day real-life challenges were put on the agenda in the program:

> "We have looked at how 2D barcodes on food products can combine these with a food waste app. So that you can easily gain knowledge about the date and proper storage, and how to use foods that soon end up all to avoid food waste."—Mats and Freja, pupils

> "We also did some exercise on emission calculation here—a sort of CO_2 Footprint Calculator, where you are using the same type of technology, you could compete with your friends to see the carbon Footprint of your meals."—Peter, mentor

Working with technology gives us the creativity to explore the use of technology to address current societal challenges. In these examples, it can be seen that the interest in learning about food-related challenges such as food waste and carbon impact from different dietary patterns went hand in hand with the orientation towards creating a solution to the everyday life of a consumer. As such, the opportunity to work with cutting-edge technology was rated highly.

We learned that putting emphasis on young people as co-creators in developing activities and events has great potential. So the ideas and opinions of pupils are valued and used in the development of learning tools/workshops. One of the mentors involved in the food waste literacy pillar expressed pride in having been working with the pupils for a long time, making them able to demonstrate the outcome themselves:

> "It's the big opening today but we've been working with the kids here for 18 months around the ideas of food waste, safety and barcodes. And here we are—kids will tell you more about it."—Mats, mentor.

It shows that participating in a very goal-oriented function can act as a motivational factor, according to mentors. For the mentors on their side, it had a clear value that they could show social responsibility to the outside school while also bringing in some visibility. We also realize that learning goes both ways—to the pupils and the mentors.

4.1.4. Addressing Real-Life World Problems to Stimulate Pupils' Passion for Learning

Engaging young people in relevant real-world problems is one of the essentials of Project-Based Learning. We learned that the case of sustainable food practices fitted well with this way of learning. Moreover, the fact that this could be driven by personal interest and boosted by a peer-oriented way of working was one important learning insight:

> "You engage people in computational thinking and activities that need to have real world relevant projects to them. It needs to be passion driven, need to be together with peers."—Peter, mentor

As expressed by one of the mentors, working with real-life problems seems relevant, and it might give more passion to the pupils. It will also be easy to work in an experimental manner as pupils are aware of the challenge, context and relevancy of the solution.

Furthermore, underscoring the tight connection between agricultural production and nature-based solutions and resources is interesting for pupils. Some teachers pointed to the fact that relating theoretical concepts found in nature had the ability to facilitate learning about a range of different food-relevant topics:

> " . . . . . . the science became quite clear to the students in relation to being able to take some of the concepts and things we have talked about and what we have learned about, that is, acid and alkalis, pH value, we have been out and examine eco systems in nature, water, holes, etc."—Mette, teacher

This statement from the teacher shows the potential of project-based learning based on our examples, which can be found in nature or just in the proximal outdoors. As a result, some of the activities at school evolved around the growing and cultivation of vegetables, which are obviously important components of food system transformation. The activities emerged around the part of the food lab at the school that is attached to an outdoor growing facility. The students worked with the idea under the working title called ReGrow.

> " . . . . this is where we have re-grown vegetables that we would like to be in such a mini-greenhouse, you might say."—Anastasia, pupil

> " . . . . So you could have it in your own home. Because, there are a lot of people who don't have the ability to grow vegetables there. It was a bit like that."—Emil, pupil

Here, it is clearly seen that growing vegetables is one of the fundamental skills that pupils appreciate. It also recognizes the importance of working with topics that pupils encounter in their day-to-day lives.

4.1.5. Choosing Tangible Problems May Create Better Scientific Learning

The framing of the activities within the idea of projects offered some clear advantages that provided flexibility in the use of theories and exploration. An idea that was explained briefly by one of the teachers in a very concrete fashion was as follows:

> "It has an easier time putting practice together with the theoretical and the scientific, when you have a problem that needs to be solved."—Kirstine, teacher

Theory and experiment are exactly two sides of the same coin that go together. As teachers testify, it will also be easy to address problems when they arise, which highlights the importance of project-based learning that facilitates learning by solving problems. Furthermore, the learning activities with hands-on experiments on food made connections between science and real-life examples. One of the students, with the example of yogurt, expressed this surprise as follows:

> "I was surprised by how they made yoghurt. That you put something in—which I don't remember, what was- and then it turned into yoghurt, I couldn't understand it at all at the beginning."—Livia, pupil

In more interviews, the students reported that many of the learning insights that they gained throughout the process could be recognized in their daily interactions with different food environments. This, we find, is an important part of food literacy. Understanding the food technological principles of fermentation obviously also has the potential to reduce food waste.

4.2. Engagement of Various Outside Actors as Mentors That Creates a New Learning Space

In this category, the focus will be on the relevance of engaging outside people in in-school outreach activities as a mentor. The important aspect here is to understand how to include mentors as a part of the project and facilitate learning on both sides.

4.2.1. Invite an Outside Mentor to Make Learning More Formal

We learned that using mentors from outside has a lot of potential when it comes to using student-driven learning approaches. Mentors can be brought in from research-based businesses or directly from the university. Since many of our learning tools in the Living Lab were quite technical and knowledge-intensive, this loop became rather important. Obviously, researchers can bring important information that pupils can use to develop their installations and workstations and to prepare for being able to explain them. Being told and instructed by a mentor was perceived as valuable by students. As one pupil phrased it:

> "I found it very exciting when there are some people who can tell us something. They know something about food games, but they can also show you how. It can seem more interesting and more exciting when you have been told something about it."—Luna, pupil

We found that besides being able to assist with valuable knowledge, direct and personal contact with "somebody from outside" was viewed as positive and as a break in the sometimes monotonous daily life at school. As such, the modeling and vicarious learning dimensions of using mentors should not be underestimated. We found that this approach has a general potential for universities to learn from society and people.

According to the teachers who participated in the program, the Science2School cooperation tended to loosen up, reducing some of the stereotypes that exist about researchers, science and the university. One of the teachers phrased it in the following way:

> "They might think it was a boring professor type who was sitting somewhere far away. . . . So that you're not a Professor locked in an office behind a lot of books."—Kirstine, teacher

It shows that project-work together with mentors will help students gain an understanding of various professions that they might want to follow in the future. So mentoring is allowed to not only exchange knowledge of the chosen subject but also familiarize one with various professions on the job market.

4.2.2. Collaborating with Mentors Requires Planning and Structure

The problem-based, problem-oriented mode of working is new to most schools. We learned that in the case of Science2School cooperation, schools were a little more positive compared to other types of "invitations" from the outside world. At the same time, it was part of the school's attempts to bring gardening into the school's ethos. The school already had a strong interest in developing urban school gardening in its teaching but had not been so far successful in doing so. As one of the teachers expressed it:

> "I would like to see the connection between the university and the schools improved. It became too fluffy for some colleagues who became frustrated from time to time. They clearly called for structure and an intermediary."—Søren, teacher

The statement clearly states that collaboration between the school and outside mentors requires a structured approach, good command, and an understanding of the school's ethos. There should be a clear plan for the contribution of mentors and the good practices that mentors also engage in with pupils. However, none of the schools had any previous experience participating in science events outside of school. For most of the participants in the project, the activities had a strong flavor of novelty. As such, the SESAM program had a certain flavor of "walking on the wild side". One of the teachers described the experience as follows:

> "We just did something in the unknown, and hoped that it would hit the spot."—Karen, teacher

The statement shows that teachers had a strong feeling of being involved in something extraordinary. Although it was perceived as challenging, it was also considered one of the assets of the project. We also found that schools, in most cases, have agreed on priorities for open schools and community outreach, but that these ambitions encountered trouble and inertia when it came to realizing such priorities and goals under a project umbrella and with external partners.

4.2.3. Using the PBL Approach to Facilitate a Sense of Collaboration among Actors

In particular, in the cases where we brought in mentors, it became clear that the cooperation developed in two important and interesting interconnected ways: as a solution to a challenge and as a learning-oriented way. It became solution-oriented in the sense that it focused on developing specific installations, mock-ups and prototypes. In addition, at the same time, it became a learning space for students and the attached mentors. As one of the mentors stated it:

> "This is also a playful way to have a competition, but also allow students to see, how much carbon they could generate or a playful kind of experimental game to see how we reduce that."—Peter, mentor

In some cases, the learning and design activities turned something into a competition that made learning for pupils more playful. For instance, an experimental approach was used to obtain an idea of the carbon emissions, and students were able to learn about the topic while designing the solution in a playful competitive way.

Since the school was already align with the principles of Project-Based Learning (PBL), it came as no surprise that working in a project-based manner generated strong resonance:

> " ... In other words, I think that from a project-based learning point of view—the school's point of view—you might be able to say the problem—is a little tight. As we have an overall framework for the project, where we (School ed.) are very happy. ... This approach where we start saying—we have a problem—do something about it fits well in our PBL work. Next step is just to add some sub-categories so the solution can be operationalizing."—Kirstine, teacher

It shows that the PBL approach is not just a good case for the learning of the students but also a good case and opportunity for the teachers to collaborate with external partners and learn from professionals in the community. However, working with projects was sometimes challenging in terms of resources, and it seems that schools could benefit from having a strategy and operational framework for external collaboration in place that would support teachers.

4.2.4. Project Orientation, External Collaboration and Challenges Can Create Authenticity

Being a project-based school means that teaching takes place primarily through projects, and project topics are the subject of the teaching. Organizing teaching in a project-based approach means teaching about ongoing and real-life issues by interlinking science and practices.

> " . . . and we prefer authentic projects with a lot of partners in order to make it as realistic as possible."—Mats, teacher

This, at the same time, introduces some challenges and requires quite a bit of planning and external relations. This was not just ordinary class planning; it was more challenging.

> "So, of course, there is something in the planning. Where you can hit a challenge in and with that also depending on the size of the subject and interdisciplinary subjects and projects, that there may be something that is set aside for a period of time."—Kirstine, teacher

> " . . . But if you are a general primary and lower secondary school with a standard form of Danish, nature and technology, Physics, chemistry, etc. then it's a bit difficult to get the lessons out to the project, since you tend to become locked in your schedules. Where, in principle, we can move our hours around so it fits in. So I think that it's about flexibility in the Danish primary and lower secondary school."—Mats, teacher

More of the interviews revealed the fact that teaching with this approach requires a little more effort and greater flexibility, which was not seen as a problem that could not be overcome. In some of the talks and interviews, teachers pointed out that they saw these projects as an opportunity to add knowledge and skills that fit well on top of what they had already taught pupils in general teaching. Being able to add some authenticity was seen as an advantage.

> "Now it's just been put into something authentic, which means that the children think ' not, we can use it for something. And not something we just have to read about in a book."—Kirstine, teacher

Engaging young people in food system issues and their digital aspects is an ambitious goal that should involve aspects of science and an understanding of technology. It shows that setting out to prepare over several months in order to be able to present something tangible and visible at the final science night was an ambitious but realistic goal for schools. Furthermore, months of preparation became a valuable source of learning for students, and having a set goal of being able to present at the end of the project functioned as a strong motivational factor.

4.3. Project-Based Teaching That Could Familiarize Real-Life Societal Challenges

In this category, the focus will be on the relevance of project-based learning in school as an outreach activity that facilitates learning for multiple actors. It also means how school settings can be utilized to learn and develop solutions for young people while still being part of the school's learning program. The main question of this section is: how do we implement the school learning lab approach in a better way so all of the actors are equally benefited? So it will explore and provide feedback on implementing the learning lab concept in a school setting. Furthermore, the experimental approach can be seen as one of the applications of the STEM teaching approach in creating practice-focused solutions. So by adapting PBL and STEM teaching approaches, it becomes obvious and will be explored here.

4.3.1. Project-Based Teaching Requires Good Communication and Good Didactic Models

Although positive towards mentoring and the open school approach, teachers report that they lack an administrative intermediary at the school that can be responsible for communication between the university and the school. One teacher suggested taking project literacy and project skills into account and taking an extension of the preparation time into consideration:

> "In terms of the period, the biggest challenge is that we have had too little time to plan the process. Next time, we will hopefully know in advance when things are going to kick off."—Søren, teacher

It shows that school planning is much different from the planning that is introduced in a project that comes from outside, even though it fits well with the open school idea that most schools welcome. More of the teachers found that the preparatory phase at the schools with the SESAM learning themes in the back of their heads was a bit too hectic to complete the project as the communication line did not have a clear structure.

> "I think, I could have used a clearer guideline for what kind of process they would like us to have as teachers. We should have had better didactic tools and they should have been better disseminated."—Søren, teacher

It is clear to the teachers what the purpose of the project is in relation to the students' outcome, but it is unclear how the teachers should facilitate this. As part of the communication and administration processes, teachers lack clear guidelines and announcements from the university. It is not clear from the outset what exactly it is you want to achieve and how, nor what process is to be used to accomplish this. It is clear that teachers should be given and provided with assistance to prepare to bridge science topics with activity-based teaching.

The STEM teaching approach introduced a more project-based and explorative way of teaching that was found to be challenging. Some teachers expressed the view that working with the STEM focus made the teaching a little more abstract and intangible, and thus also more challenging. As one teacher expressed it:

> "It's just really hard to have to work inside this with STEM and project work in general, and that's because it's becoming very intangible in relation to methods and application."—Mats, teacher

Working in the project and STEM mode was seen as something new, desirable and challenging. In particular, working in a project-organized mode seemed to introduce a demand for new types of skills. As one teacher phrased it:

> "I believe it is also a question of how you as a teacher might not be quite as well trained in how to conduct research based teaching in this way. Because there is actually no time for that."—Mats, teacher

Again, the teachers find the facilitation process difficult due to the lack of materials that are translated from research to teaching material. This obviously introduces a need for new kinds of skills, knowledge and competence among the teachers, as one of the teachers expressed it:

> "If I'm better equipped and the focus and framework for the project is taken up more sharply, the project has a huge potential."—Anna, teacher

Besides suggestions for these needs, the quote also indicates that working with external mentors for project-based teaching requires planning and good management among the project actors. Furthermore, the STEM teaching approach requires knowledge of multiple subjects and their application in a scientific manner, which might be difficult for the teacher with particular subjects. The difficulties of implementing STEM and project-based teaching approaches can be simplified by clear teaching guidelines.

4.3.2. Balancing between the Pupil's Autonomy and Guidance from Mentors in the Project Works

On one occasion, we observed a group working to apply the scientific principles of fermentation and set up an educational mini-dairy fermentation pilot plant. The group worked independently and arranged for themselves to be in the back row of the room, which both gave rise to independence but at the same time put help from the teacher within reach. The students distributed the tasks between them and were found to be working patiently and in a structured manner toward their goal of making a yogurt-based recipe. The group generally worked independently without much supervision from the teachers, and at the same time, the PBL framework in some cases gave rise to some challenges and disagreements along the way. As the observer's note explains:

> "Mathilde says that there is no more than half a litter of milk, because the cheese group also has to use milk. The girls agree to ask a teacher because the recipe says that they need a whole litter. Mathilde is standing up to the table and is standing up, while she insistently looks at the teacher who is in the cheese group. . . . A couple of other groups also need to clarify some questions Mathilde is steadfast, patient and quiet, but still with insistent questioning gaze, until the teacher finally gets down and says that they have to adjust the recipe according to the amount of milk they have, and that they can do it themselves."—Researcher observation

It clearly shows that from time to time, some uncertainty arises in the group when the students feel that the instructions and the assistance available appear to be insufficient. This, in some cases, led to frustration and controversy between pupils as they could not reach an agreement on how to solve the tasks within the didactic structure of the project. It also means that a project-based approach should have a plan for how much experimentation the pupils should do and how much interference the mentor should consider doing. Some students mentioned that this way of working had contributed to the strengthening of their motivation and said that they were pleased to have been allowed to work independently. They also mentioned that variation in learning approaches, the "fun" element—the surprise element—and the experience learning components were appreciated. Students described that as follows:

> "You decided just like yourself—it's also a bit more fun. And it was also just something different from food at school than usual. This is not something you have tried before."—Maria, pupil

> "Yes, and if we use different learning methods to learn different things, I also think it will be easier to learn it."—Rasmus, pupil

We see this as an appreciation for trying to create diversity and variety in teaching. Furthermore, the new way of learning is regarded as a convenient learning approach for pupils. This approach can be seen as creating a somewhat alternative way of working with food. Students appreciated the autonomy of working, and they liked the surprise element that developed throughout the learning process. It underlines that experiential learning comes closer to the idea of edutainment—the idea that elements of entertainment can be utilized as a means of learning. We also learned that the "fun" part was important for pupils, but also that working in project mode was challenging and something students had to get used to. As one of the observer notes explained:

> "She explains that she does not think it has always been so fun, when she has been in a group with people she does not know. But it's fun with this group because we're doing a lot of fun, but we're still doing something."—Researcher observation

It further proved that the "fun" part seemed to be an important driver for students' motivation for learning. Working in a group might be a hindrance in the beginning and a source of "fun" as well.

4.3.3. Linking Technology and Food Can Be the Perfect Storm for a STEM Teaching Approach

An important part of the activities in the lab will soon turn digital. In other words, understanding digital technologies and data became important learning components. We found that it matched well with the aims of the SESAM program, including the ideas of understanding facts and making decisions based on data. As one of the technical measurements puts it in this quote,

> "The idea is to turn these into activities for different schools to use computers to explore concepts like data and privacy. And to create a relationship between math, science and computers. And at the same time to design technology for relevant problems, especially in the food waste area."—Peter, mentor

We saw that this approach also matched well with the ambitions of the teachers, in particular in the math classes, since there is quite some interest at the school level in strengthening the teaching of data in all its different connotations. Making the match between data and green food system transformation became very straightforward in the case of the project, where students immensely worked with food waste mitigation solutions.

The STEM teaching approaches to learning about food that were at the core of the SESAM program had a spin-off that allowed for involving teachers with biology, math, physics, chemistry and computational thinking as their subjects. This added a whole new and cross-disciplinary dynamic to the process. Several pupils described during the interviews that they did not know much about the science focus of the project in advance. Instead, they were under the impression that the focus should be on cooking. As a result, the real focus came as a positive surprise to the more science-interested pupils. One student reflected on its relation to the natural sciences:

> "At first it was not what we had expected, but I like that we gradually went a bit more into the direction of chemistry and physics."—Oliver, pupil

Students seem to like the experimental cooking approach that was driven by the school science agenda and its ability to link to underlying sustainability-oriented biological principles of food and shelf life. When students were asked to reflect on the sustainability aspects of their project, however, they were not sure, which can be read from the reply by one of the teachers:

> "She says that she has learned that you extend shelf life of food if you do something about it. Just like the cheese. I ask her why she believes it is sustainable. She doesn't know what to answer. She thinks it's difficult."—Søren, teacher

Nevertheless, the students demonstrated an understanding of how the shelf life of foods can be extended, which is in line with what they have been introduced to by the teachers. However, the student was not able to explain how shelf life is related to sustainability, which was seen in several of the groups. We see this as an underlining of the need to highlight the connections and links that exist between food processes and sustainability aspects. Through the teachers' enthusiasm for the natural sciences, they were able to add a new dimension to the learning about food that acted as a good basis for the subsequent project-work and that also created attention among the science-interested students.

4.3.4. Real-Life Problems for Projects Works Can Help Pupils Match Problems with Solutions

We found that orienting the learning towards something that is solution-focused was valued by the young people in our program. As such, it indicates that the work not only contributes to learning among young people but also has the potential to create new ideas for solutions that might even be valuable in real life. One instance of that we found in the work with food waste issues, where the task was oriented towards obtaining circular food thinking integrated into students' mindsets.

> "We worked on a project where we examined whether you could use something of an overcut vegetable to grow a new one, to avoid food waste. And we demonstrate that we could!"—Marius, pupil

It shows that exploring something related to our daily food activities can add something valuable to our understanding of both the problem and the solution. It will give a better understanding of the knowledge when it will be applicable if they have to.

Teachers pointed to the fact that being able to cater to both academically strong and weak students is seen as an absolute advantage. Different pupils have different ways of learning and understanding levels that teachers need to consider. The teacher in the interview underlined the opportunity:

> "This is the good thing about running project-based teaching. Everyone has some competences to offer and, depending on the student's interest in background."—Kirstine, teacher

> "But also in relation to the fact that you have the opportunity to give the academic strong pupils some challenges. In the meantime, there are others who may not be so academically strong to solve some other challenges. So in other words, there is really a room for being able to differentiate (challenges ed)"—Tina, teacher

The testimonies from teachers show that the PBL approach provides room for both strong and weak students by giving them the opportunity to explore their competencies. In addition, it also provides room for equal opportunity for pupils to use their unique quality of learning.

There was quite some agreement that some of the project activities, in particular at the beginning, had been confusing due to the lack of clear guidance. Properly defined challenges and clear guidance on projects facilitate better engagement of pupils, which students explained in the following way:

> "I think this (the project) was very cool, but the teachers have not been particularly good at explaining exactly what you need to do. It has been a lot like that for day-to-day. So the teachers will probably explain it much better, so you understand it. (...). But otherwise it's been a pretty cool week. I think I learned a lot"—Ada, pupil

> "We have done a lot of projects so far, and it has always been a bit the same, but now it started to become easier to communicate with others when you do projects so many times."—Emil, pupil

As reflection indicated, clear guidance on project themes, pupil involvement and the working plan would be helpful for better implementation of the learning plan. As pupils tend to work in groups, clear guidance will help the group function better. Otherwise, it tends to create tension among group members. It is also considered that teachers also need to have clear guidance on what and how to guide pupils in the project to make sure pupils are explained enough. It is reflecting the need for clear guidelines for the project to the pupils for what they are learning and its relevance.

4.3.5. Balancing Practice and Theory May Motivate Pupils for Learning

In many of the activities, we had discussions with teachers on how to best motivate the pupils. Teachers learned that they often have a choice between using a text-and-blackboard way of teaching and a practice-based way. This became clear in the part of the activities to develop digital technologies to tackle food waste in families. During these activities, we made extensive use of scientific theories and mentoring to bring new technological solutions to the table.

> "A book-based academic part would be extremely boring for many kids, but simply slamming this new barcodes and some app making tools on the table motivated them (the pupils, eds) them in a very positive way."—Kirstine, teacher

The inclusion of extra activities in addition to academic books might be motivational for pupils, as seen in the above response from one of the teachers. Digital technologies seem to be able to increase both the engagement of pupils and their interest in learning. Working in a practice-oriented manner was also perceived as an advantage by some students. As well, starting to build and construct things seems to be appreciated as a kind of experimental approach.

> "It was quite clear that it was more practice. That we could go into it and do something from scratch. It has also been easier to remember things, so that it all fits better into the full picture."—Emil, pupil

The students clearly benefited from the fact that the teaching is disseminated in practice in a way that uses familiar theory. This has contributed to a better academic understanding.

> "Yes 100% and create more interest in the natural sciences, because there has not been so much theory and we have to create something ourselves. I think that all of you like that, all young people, instead of, because a lot of theory can be dull in the long term."—Ada, pupil

The practice-based teaching has also increased the students' interest in and commitment to the project. This is clearly a motivating and attractive form of learning.

> "Yes, I also think it can be very heavy if you only make written assignments, only make reading material, so I think it's also very exciting, but quite clearly the alternation between the practical and the theoretical has made a difference."—Liv, pupil

The idea that science and sustainability could be communicated in a "less theoretical" but "more practice- and experimentally-oriented" manner was appreciated by both teachers and students. Natural science subjects, such as biology and physics, are important but, in many cases, perceived by students as not interesting. In that way, the practice was taken as a road to subsequently understanding theories and making learning more exciting, which was also well received from a science teacher's point of view.

4.4. Summary of Analysis

Summarizing the results from the analysis of data shows us that the Living Lab format can serve multiple purposes: (i) as an important solution provider that acknowledges the value of solutions from young minds, and (ii) at the same time as a learning lab in which multiple actors from the local community can engage in creating valuable solutions. As such, the Living Lab is a good way to create action, engagement and empowerment, which allows us to serve the purpose of both Living and Learning labs.

The data analysis shows that the user co-creational concept of the living lab format can alleviate the explorative way of learning and help the pupils better understand contemporary issues. The user co-creation concept can also act not only as an important source of inspiration for solutions that acknowledge the value of young minds but also as a multi-actor learning lab in which different actors from the local community can engage in creating valuable solutions.

The living lab format is well suited to creating cross-community engagement around topics related to, for instance, green food system transformation. The presence of an outside mentor is taken as a milestone by pupils and is able to make their learning more formal. However, collaborating with outside actors as a form of mentorship requires structure and a format where each actor has a role and space for learning. A project-based teaching approach that can be part of the living lab format also facilitates a sense of collaboration among actors.

The result of the analysis also shows that working with real-life societal challenges can be outstanding, which can go hand-in-hand with both project-based teaching and the Living lab approach. The Living lab format in a school environment can facilitate the learning of both theories and practice from an external mentor. Project-based learning can be a useful tool to engage multiple actors and, at the same time, experience both the theoretical and practical aspects.

The Living lab approach in a school environment can be a way to create action, engagement and empowerment around urban food issues. Project-based teaching requires a good didactic model, which can also be achieved through the living lab format in a school environment. As such, it has the potential to act as a tool for cross-community engagement around specific topics related to the transformation of green food systems.

5. Discussion

Overall, we find that the Living Lab approach is able to explain in a meaningful way how a learning space for pupils can be created alongside an innovation and interaction space for the benefit of multiple actors in the local community. However, the result of the data analysis and evidence from previous literature show that the Living lab approach can have some limitations in relation to the engagement of young people and learning possibilities.

5.1. Young People's Involvement as a Co-Creator in Order to Facilitate Learning

User involvement is a key element in the Living Lab approach [22,23]. As such, the active participation of pupils as co-creators of learning tools in the school learning environment was crucial in the SESAM learning lab of this case study. The traditional approach to innovation in sustainable food system transformation is that it is supposed to be driven by academia, scientific insights and technology. However, it is found that mentoring in a living lab context has the potential to create what is sometimes referred to as a knowledge triangle—an environment where innovation meets education and research in a shared learning and workspace [12].

Exploring the world through children's eyes provides more awareness about the current challenges that we are facing, such as environmental challenges [10], and a study shows that pro-environmental thinking practices were very effective learning tools [41]. The interactive workshop can help explore children's cognitive thinking about context and future perspectives. In addition, students' engagement and activities can reveal what kinds of activities and/or perspectives are more engaging for various groups of students, for instance, boys and girls [33]. In this regard, the experimental approach that underpins the living lab approach seems to act as an important motivational factor for pupils, which facilitates experiments to create something. The result of the data analysis shows that a higher level of young people's involvement can be achieved by using tangible set-ups such as installations, experiments, demos, workshops or prototype-oriented solutions that give a sense of co-creation to the students. Everyday life approaches, and the food topic can be part of the experimentation. Starting with the practice and following that up with the theories will make more sense to students.

One of the experiments with didactic activities planned for kids about food chemistry shows that research-based teaching practices were very effective in increasing young people's engagement. The learning activities followed three steps of the learning cycling approach: "*concept invention*", "*application*" and "*process of exploration*". The teaching cycle is constituted by "reflecting on teaching/learning","modifying the pedagogy" and "assessing the success" [18]. Such a teaching approach seems to be perfect for young people's engagement.

Overall, we found much support and liking for the SESAM living lab approach, both among teachers and pupils. However, we also from time to time identified some weaknesses related to the fact that the students had to work in project mode and in an independent manner, where they were expected to choose particular directions on their own. This participatory, self-contained mode meant that teachers were supposed to stay in the back to intervene with pupils only on demand. We observed that in some cases, pupils had a need to maintain an overview and stay focused, which in some cases limited their ability to work independently on the assignment.

5.2. Outreach to the Local Community and Engagement across Different Actor Groups

The outreach program can be designed in various forms with various goals, for instance, Citizen Science events that connect science research to citizens [42], or field visits to local communities, and so on. The school outreach program can help bring multiple actors, such as students, teachers, researchers and industry experts, closer. The school outreach program can also improve understanding of the impact of the work of researchers on daily life, future jobs and encourage young people to pursue a scientific career [29]. Previous evidence clearly shows that outreach activities can help increase interaction between academics and society in relation to the application of science in society [23,25]. However, whether the students' contribution to science, valued by scientists, impacts a wider understanding of science in the student's life is yet to be explored in research [29].

A one-day event-type outreach activity for students (encouraging scientific citizenship) has been effective in helping students understand the impact of the work of researchers on daily life and encouraging young people to pursue a scientific career. Furthermore, parents can learn about the required education and academic opportunities for their children [43]. The demonstration of a technological product or service will allow students to learn about its technical aspects, its potential and benefits, as well as obtain feedback on the demonstrated technology. So one-day event-type outreach activity from either academics or the industry could start a wider collaboration with the local community and the schools. Traditionally, schools have been working within a curricular framework in which core subjects have not changed a lot over the past century, so they are not used to working project-based. This has tended to create a kind of silo-like thinking in which teachers have developed teaching that fits with politically decided learning goals. However, in a transversal kind of thinking where learning is created around multidisciplinary themes such as digitally driven food systems transformation and that requires teachers to apply knowledge from different fields, such as Biology, Mathematics, Chemistry, Physics and Technology [37]. As a result of combining the traditional school's fixed curriculum with transversal thinking that needed to work together outside the traditional vertically oriented division of school subjects, we encountered significant problems in many cases. Project-based teaching requires great deals of collaboration with different partners, and a lack of know-how on how to engage in projects with external partners can affect the outcome [20]. Engaging home economics teachers in project-based teaching for food literacy who already had food on their list of subjects was straightforward. We found soon that the work on food waste was recognized as being part of SDG 12.3 (Sustainable Development Goal). Working with SDGs in the school environment is high on the agenda, so any links and synergies between food and SDGs create resonance. In general, we find a very high level of commitment and interest in schools and among teachers in working with SDGs and in using the principles of Education for Sustainability, and this fact should be taken advantage of when developing food education at school.

5.3. PBL and the School Environment as a Potential Living Lab

School settings could be one of the most effective routes to food system learning, and the use of contemporary digital technologies is an effective way to incorporate learning about the green food system transition [37]. The analytics clearly show that schools work at a different pace and in a different mode compared to universities and outside organizations. A living lab approach creates opportunities to cross these boundaries with meetings, events and gatherings that can allow for learning from each other [22,23,25].

The SESAM learning lab's aim to increase science, digital and food literacy is related to being able to adapt to the "projectified" nature of the program, which is perceived as a challenge by the school due to the required communication and working structure. This is supported by the fact that in most cases, the school uses a very long planning frame and a didactic approach, whereas the SESAM program in this case is based on project-based teaching, with much project- and group-based work that needed spontaneous planning. Working with two different types of schools, it has been learned that it would be easier to collaborate if the schools had clear strategies and objectives to achieve. One of the collaborating schools has a PBL strategy in place, which allows school teachers to be more explorative in their teaching approach [20].

The central element in the school-project activities was the technology aspect, which was seen as a positive thing that is very much in line with the emerging school subject of computational thinking and technology understanding. On some occasions, teachers felt digital skills were a challenge and experienced that the pupils were, in some cases, more skilled than themselves. In that sense, it became clear that teachers tend to feel a need for stronger digital competencies. Working with sensors, microcomputers, robots and other kinds of digital devices to create concrete and tangible solutions (installations in this case) that can contribute to food systems transformation thinking makes digital literacy a crucial component in developing STEM learning activities [20,34,37].

6. Conclusions

The analysis clearly shows that the Living Lab format can act not only as an important solution provider that acknowledges the value of solutions from young minds, but at the same time can be a learning lab in which multiple actors from the local community can engage in creating valuable solutions in relation to food. Using the Living and Learning Lab is found to be a good and meaningful way to create both action, engagement and empowerment, and in particular, we find that it is well suited to create cross-community engagement around topics related to green food system transformation. Furthermore, the living lab approach can facilitate various experimental teaching practices, for instance, the STEM teaching approach, PBL and experimental learning.

Mentors can be brought in from various fields, for instance, research-based businesses, universities, or start-ups. Early-career researchers can be very relevant due to their flexibility and interest in exploring new challenges. It also makes more sense to involve early-career researchers in engaging with young people, as it can be a powerful source of learning in relation to future career choices. Engagement of outside actors can be performed with various concepts to make it more win-win for actors. Corporate Social Responsibility (CSR) is one of the good approaches that involves industry expertise. The actors from industry can be utilized to provide literacy about Sustainable Development Goals (SDGs) to young people. It also provides a whole new opportunity to work with cutting-edge technology and contemporary societal challenges.

Project-based learning (PBL) seems to require project skills both among teachers and kids, as schools are not used to working project-based. Engaging home economics teachers in Project-Based Learning for food literacy who already had food on their list of subjects was straightforward. It also shows that pupils' main experiences with food in a school context came from home economics classes. The "from practice to theory" approach seemed to work well with the Project-Based teaching approach, which could be an important foundation for the Living lab format, such as in the case of the SESAM living lab. The project-based and group-based approaches without too much traditional blackboard teaching were highly valued by students.

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Institutional Review Board Statement: Participants for this study were recruited through the LinkedIn network of the PI so there was no need for any particular GDPR approval since accepting invitations on LinkedIn automatically means that the person gives permission to be contacted for professional purposes. As regards to the ethics, we used the "Researcher rule" that allows Danish universities to collect data of interest in examining topics of general societal interest. Since the data collected are of non-sensitive nature researchers are allowed to collect data without permission from the research ethics council as long as informants are informed about the purpose.

Informed Consent Statement: Acceptance to participate based on information in a handout. For the minors in the study, the school maintained a procedure for recruiting pupils where parents/custody holders were informed about the purpose of the study and where only informants that had permission were included in interviews. All interviews were initiated by an opening where participants confirmed that they had been informed by the purpose of the study and that they gave permission to record the interview and use it as part of the research process.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the privacy of the informant.

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