Green food transformation systems
Role of young people in engagement and digital literacy
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ABSTRACT
Food and agriculture systems have been under pressure due to climate change. Food production and consumption are known to cause up to one-third of climate impact as they occupy a large part of land for animal feeding and a significant amount of food is wasted. To reduce climate impact, therefore, food systems need to incorporate constructive approaches. These include aspects of production, distribution, consumption and disposal. It requires new digital insight and capacity-building to interpret the changes. Schools can provide an excellent arena for these changes because of their infrastructure and wide reach in society. Against this backdrop, the Sense, Science and the Magic of Food (SESAM) programme set out to study whether learning about food systems transformation could be achieved by incorporating contemporary digital technologies. The SESAM programme took place in four elementary schools (teachers: n = 12, pupils: n = 300). We developed four learning stations with a food and cultivation theme, as well as digital themes such as a simple aquaponics plant with data collection sensors, a programmable robotized raised growing bed, an artificial light-driven vertical mini farm and an

KEYWORDS
- digitalization
- digital technology
- learning strategies
- urban food and farming
- problem-based learning
- project-based learning
- STEM principles
autonomous programmed drone-based delivery service. The report shows that the programme was able to create important learning around food systems transformation in a school setting and was perceived as a relevant route to Education for Sustainable Development Goals (ESDG). In particular, the strong focus on science, technology, engineering and mathematics learning principles, project-based learning and the digital element was rated high. On the negative side, we found that teachers’ competencies are a crucial element and that a programme of this kind is time-consuming and needs the right type of external assistance if it was to be scaled up.

INTRODUCTION

Food production and consumption are reported to cause up to one-third of human-caused climate impact. The agriculture sector, together with forestry and other land uses, contributes nearly 25 per cent of total global greenhouse gas emissions (GHGs). Half of this comes from direct agricultural emissions, mainly from livestock, and most of the remaining half from deforestation that makes agriculture an important determinant of climate change (OECD 2012). Agriculture occupies around 60 per cent of Danish land (Arler et al. 2015), and on the consumption side, almost one-third of food purchased by Danish households is wasted (DCA 2018; Gustavsson et al. 2011). In order to create a food and agricultural system that is more resilient and meaningful and in order to reduce climate impact from food and land use for food production, it is necessary to transform the food system to more plant-based food and to reduce the amount of food waste (Hedenus et al. 2014; Sachs 2019). This requires radical transformation of the food system, including aspects of production, distribution, consumption and disposal.

Digital technology has often been referred to as one of the game changers that could support the stainable transformation of food systems – for instance, by introducing sensors and intelligent machines for agricultural production (Rounsevell and Harrison 2016; Bilali and Allahyari 2018), using gamification in sustainable nutrition education (González et al. 2016; Yoshida-Montezuma et al. 2020), for smart collection of food consumption data (Ofei et al. 2017; Nevalainen et al. 2018) and for automatic recognition of food pictures for dietary assessment (Ofei et al. 2015; Dehais et al. 2016). In addition, several policy documents from the World Bank, the United Nations’ Food and Agriculture Organization (FAO) and the Organization for Economic Cooperation and Development (OECD) emphasize the role of digital technologies for food system transformation (Lajoie-O’Malley et al. 2020). However, digital technologies are not going to revolutionize food systems without incorporating the necessary structural conditions, such as education and other types of capacity-building (Ananiadou and Carlo 2009).

In the future, agriculture and food systems can greatly benefit from applying already operational or developing technologies, such as robotics, nanotechnology, synthetic protein, cellular agriculture, gene editing technology, artificial intelligence (AI), blockchain and machine learning (Klerkx and Rose 2020). Food systems transformation will require changes in the way we as consumers purchase, prepare, eat, share and dispose of foods. As a result, learning and modifying strategies are more important than ever before. School
settings offer a well-suited arena for capacity-building due to their well-structured professional arena that has reach and representation across society.

The idea of linking food education and learning about Sustainable Development Goals (SDGs) to educational interventions at school is not new, although research has been limited (Carlson and Williams 2008; Meek and Tarlau 2016; Sadegholvad et al. 2017). The concept of education for sustainable development created by UNESCO has been around for a long time and is widely used in schools. According to Corner et al. (2015), despite decades of research on effectively communicating climate change to the general public, only recently has research been published on how young people engage with climate and sustainability education (Bergmann and Ossewaarde 2020; Sabherwa et al. 2021). And, to the best of our knowledge, studies on how education for a digital future can be linked with education for sustainability have been lacking. Taking into consideration the increased engagement of young people in climate change and the close relationship that exists between climate and human food practices, there is a strong rationale for developing new approaches to food education at school that use climate action and the SDGs as a foundation (Ananiadou and Carlo 2009; Andersen et al. 2018; Griffin and Care 2015).

Science, technology, engineering and mathematics (STEM) learning principles embrace the key elements (may be called 4Cs) in twenty-first-century education: Creativity, Collaboration, Critical Thinking and Communication. The STEM principles incorporate project-based learning to address various needs of learner that help to foster a love of learning.

The aim of this article is to present and discuss the first insights from the Sense, Science and the Magic of Food (SESAM) programme in order to be able to develop research directions as well as guidelines and recommendations that can be used to replicate, scale up and improve science and digitally based food systems education in schools.

Conceptual and theoretical foundation

The SESAM programme was developed as a means to create learning about green food system transformation among young people in schools. The idea was to stage the learning around contemporary aspects of the food system in order to create resonance and recognition among pupils, teachers and visitors. We picked topics that were high on the agenda in food system transformation debates, including topics such as aquaponics and vertical farming, drones and food chain mobility, agriculture and land/energy use, soil health, biodiversity, food waste mitigation and food chain traceability. In the choice of topics, we took inspiration from pupils and teachers as well. Didactically, we built a programme around the concepts of project-based learning, citizen science in the classroom, the idea of twenty-first-century skills and computational thinking.

Project-based learning builds on top of the problem-based learning (PBL) principle developed as an alternative didactic approach in medical schools during the 1960s. Over the past decade, however, it has been revived and found its way into elementary school teaching (Bell 2010; Ferreira and Trudel 2012). The two concepts are often used rather interchangeably and have developed as an alternative didactic approach to the traditional subject-oriented approach used at schools. It sets out to explore a given problem through the application of different relevant subjects, organized as a project. In our case,
more emphasis was put on the idea of understanding ‘projects’ as a means to focus on a particular topic or ‘problem’ for the purpose of learning. And, by using the notion of projects, we aimed at the same time to prepare pupils for a future labour market that increasingly seemed to be relevant (Jensen et al. 2016).

The concept of citizen science has unexplored potential in classrooms. It is an approach that involves participation of schools in research or mentor-led learning activities. It is increasingly seen as an important tool for both researchers and educators. Researchers can explore research questions that would otherwise be costly and labour-intensive. Teachers, on the other hand, can explore new learning processes for their students where researchers and mentors are brought into classrooms, thereby making their teaching more relevant and understandable (Shah and Martinez 2016; Schneiderhan-Opel et al. 2020, Mikkelsen 2018). At the same time, citizen science has a potential to create data that can be used practically for research purposes. In this way, pupils become informants in a research process at the same time as they are learning about research.

The SESAM programme is inspired by the idea of twenty-first-century skills – an idea originally formulated by the OECD to describe the skills that the future workforce is predicted to need (Bell 2010; Griffin and Care 2015). Recent learning and education research have pointed to the need for whole new sets of skills that the younger generation needs to learn to meet the challenges of future societies. These skills are often just referred to as ‘future ready skills’ and are a set of skills that are not necessarily developed through the traditional subject-oriented teaching in schools. However, such skills can be developed transversally across the traditional subjects in a project mode and include skills such as critical thinking, team skills, stage skills, creativity skills, design thinking and, most importantly, digital literacy and technological understanding.

Understanding digital technologies among young people is considered important for many reasons. They will grow up in a future where social interaction and economic transactions will be mainly digitally based and their education is increasingly governed by a broad range of educational technologies, both in classroom interactions and in the teaching that takes place in labs (Qureshi et al. 2021). For these reasons, we added that the future of the food system is considered to be highly influenced by digital technologies in the context of the SESAM programme. As such, we argued that in order to understand future food systems, one needs to understand the potential of a wide array of digital technologies. In SESAM, we took a broad approach and included a portfolio of digital technologies: AI backed by the use of open-source food and nutrition databases, augmented/virtual realities (AR/VR), use of sensors and microcomputers as well as the Internet of Things (IoT) to collect data, robotics design and simple programming.

METHODS

The SESAM programme

The SESAM programme is part of European Union Horizon 2020 research and innovation programme (MSCA-NIGHT), which is also called European Researchers’ Night. The general purpose of the programme is to create interest among young people at schools and among citizens about the role of research.
in societies as well as to increase young people’s interest in science careers to counteract stereotypes of research and of researchers. The programme (MSCA-NIGHT) runs every year in around 50 different places across Europe, with an estimated coverage of more than 400 cities from most of the EU member states. SESAM was developed to create a themed version of the NIGHT in which food and digitalization became the research case. More specifically, we chose the case of sustainable food systems transformation and the potential of digitalization to design the overall narrative for this specific version of the NIGHT. Unlike the majority of the other NIGHT programmes that use museums and science centres as their main venue to meet the public for a one-day event, we used the school as the preparatory setting where participating schools engaged with researchers and mentors for a period of three months. In this programme, students become co-creators of the final event that took place both at the school and in a downtown venue over the course of the final NIGHT weekend.

The approach of the programme was inductive in its nature and attempted to bring in theories ‘On the Go’ and ‘On-Demand’ whenever needed to understand and solve a specific problem or challenge related to a food systems topic. Whereas the ‘problems’ were related to food and growing, ‘theories’ were related to a scientific subject such as biology, math, physics, chemistry and home economics. In line with the PBL heuristic, we promoted an approach where pupils and teachers were working with authentic, real-life problems in an exploratory manner. In doing so, the basic idea was for them to choose the necessary tools, theories and methods needed for solving the challenges they were faced with. In line with the idea of citizen science in the classroom, we made provisions to organize a team of technical, digital and scientific mentors. These mentors were early career researchers and experts from private companies, and their role was to supply the practical knowledge the schools needed to develop the learning stations.

The SESAM programme took place over the summer and fall of 2020 at four different elementary schools (teachers: \( n = 12 \), pupils: \( n = 300 \)) in the greater Copenhagen area of Denmark. The final event took place on Friday and Saturday, 27–28 November 2020.

**The SESAM learning stations**

To achieve the main aim of the SESAM programme, a portfolio of learning stations was designed and developed with due focus on one or more scientific and digital principles in the context of food systems. The idea was to create a project environment with the PBL principles in mind, where students would develop learning stations in a process that strengthened their skills in critical thinking, creativity and team work. All learning stations involved one or more specific scientific principles from the STEM domain – the classes of math, biology, chemistry and/or physics. In most cases we involved also teaching in home economics. For the digitalization part, we involved, where possible, the IT teaching and/or the emerging subject of computational thinking – in Denmark referred to as technology understanding. In this way, we made sure that basic understanding of digital principles such as AI, VR/AR, robotics, biometrics, coding and data acquisition became embedded as much as possible in the development of the learning stations. All learning stations involved some kind of project planning, engineering, construction and building element, and for all of them, students were tasked with being...
able to communicate and explain the idea of their station to visitors at the final NIGHT event.

The learning stations were built on the active engagement of schools, pupils and teachers to create engagement in food systems transformation as a topic at school. The development of the stations built on co-creation based on mentoring by early career researchers or entrepreneurs from start-ups that were able to provide the technical assistance to build the stations.

All stations had an ‘edible’ or ‘cultivating’ principle and a digital and scientific principle, as seen in Table 1 and Figure 1. The primary instrument in the PBL process was a construction and engineering part – construction of a mock-up or installation of a learning station that could tell a story with a scientific and digital dimension and could work as science communication for the visitors at the NIGHT. In addition to the learning stations, the science communication at the final NIGHT event took advantage of talks and panels to highlight important aspects of science and digitally focused food systems thinking.

Table 1 summarizes the knowledge, skills and competencies that were intended to be the outcome of the learning activities that evolved around the four SESAM installations of the study.

<table>
<thead>
<tr>
<th>Learning station</th>
<th>Focus of learning activities</th>
<th>Learning goals</th>
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| Indoor Farm Station – a mini vertical farming unit | • Indoor artificial light urban farming and essential resource and energy needed  
• Ability to design, build and control a digitally assisted mini farm | • Understand basic principles of land use for food systems planning  
• Understand the principles of growing artificial light cultivation  
• Understand energy trade-offs in vertical farming |
| Farm2Fork Drone Station – an optimized drone for food harvesting | • Drones as future urban food systems mobility  
• New interconnectivity models of urban and peri-urban supply chains | • Develop programming skills to operate autonomous devices such as a drone  
• Understand the potential of autonomous devices in a food & agri context |
| AquaPonics Station – a circular farming unit with aquarium | • Circular food production, resource efficiency and micro grow technologies for urban farming  
• Nutrient metabolism for plants and fish and energy regulation using sensors | • Apply sensors to monitor, analyze, display and explain sensor data  
• Understand the sensing–feedback loop in biological systems  
• Understand potential of simple and vertical urban growing systems |
| FarmAI Station – an urban farm mock-up controlled by robot | • Robot-assisted growing in an urban context  
• Programming and AI optimizing of vegetable-growing practices | • Understand the concept of vegetable and herb growing using programming, robotics and AI  
• Explore the future potential of automotive growing in the city |
AquaPonics Station:
The station consisted of sensors for measuring temperature, pH value and nutrient value (Ammonium and Nitrate). The station used a pump for water circulation and LED lights for plant growth. Data from sensors were displayed on screen to illustrate energy and nutrient cycles.

Farm2Fork Drone Station:
The Drone was equipped with camera that allowed it to identify vegetables on the field. The pupils then trained the drone with the assistance of a university drone pilot to act as a take-away service and deliver he produce in the classroom.

FarmAI Station:
The farm consisted of a pre-built device that became interfaced with a computer acted as a farm robot. The pupils were tasked with programming the robot for simple farming tasks and engaged in a learning task where AI components to understand Machine Learning.

Indoor farm Station:
The small indoor vertical farm was equipped with artificial light to supply light to satisfy the growing needs of the plants to illustrate the potential of LED light as an alternative to sun light. The pupils were tasked with making estimations on energy and water use and potential feeding capacity of the device.

Figure 1: The four digitally based SESAM learning stations (labs) and installations.
Data collection
The goal of data collection was to examine in more detail how the design and use of digital technologies could help in the teaching of sustainable food systems transformations among young people in schools. Our primary focus was to observe and understand the experiences of the pupils, and we used school teachers as secondary informants to validate the insights. The overall research process was organized as an action research process in the sense that development of installations and data collection took place simultaneously. Data were collected during the preparation of the SESAM programme, during the final SESAM event and immediately after. The action research approach was chosen because, for the process to develop, both the researchers and the pupils were essential actors and worked together in a symbiotic relationship. The pupils and teachers were, on their side, dependent on the technical and scientific input from the researchers; and the researchers, on their side, were dependent on being able to understand both the potential and the barriers for this kind of digitally focused food systems literacy training. The research process took place over a time span consisting of planning, preparation and development of the events in the schools, as well as the events themselves. All in all, the duration started in mid-spring and ended at the final MSCA-NIGHT in late fall of 2020.

Data collection was organized as interviews and observations. The primary plan was to hold focus group interviews to understand the social dynamics and interactions between the participants through the collection of verbal and observational data (Redmond et al. 2009). However, due to COVID-19 lockdown and social distancing restrictions, the plan had to be adapted for the focus group interviews. As a result, individual semi-structured interviews had to be used instead. In total, fourteen interviews were obtained – nine with students and five with teachers.

The observations took inspiration from the ethnographic field study tradition, with the idea of both observing and subsequently talking to the pupils during the SESAM programme. The inspiration from ethnographic field study methods was chosen as it provides the opportunity to observe the class and have informal conversations with the students while at the same time being present in the field as a researcher (Angrosino 2007). The observations were used as a baseline and foundation for further interviews. For the observations, observers mingled as much as possible in the classroom to make themselves familiar with the students, with the objective of ‘becoming a part of the observation’. After the first observations, experiences and impressions had been mapped and functioned as a situational analysis, where we learned in each case how the SESAM activities unfolded and how the students experienced it at each individual school. A total of five subsequent observations based on individual field notes were collected, based on participatory observations during a period of two days in the schools.

Semi-structured interview was applied using an open questionnaire guide that listed the topics that should be covered and allowed the interviewer to invite the respondents to a more individually oriented and semi-customized conversation. This approach is well suited for exploring the perceptions and opinions of a respondent in a field where multiple cases are being studied (Bradley and Harrell 2009). The overall aim of the interviews was to learn more about motivations, to understand the type of learning that took place and to understand any individual differences that might exist between students,
classes and schools. Questions would revolve around what made the informant feel involved in learning activities and having them explain what type of knowledge, skills and competencies the activities resulted in. The interviews were also focused on understanding the possible positive impacts in terms of food, science and digital literacy among pupils and on understanding any hindrances and barriers that might exist in relation to the SESAM programme and its learning stations. Questions in this section would revolve around having the pupils elaborate on what kind of insights in food, science and digital followed in the wake of SESAM.

The aim of the interviews with teachers was to get a better grip on how such kind of food systems learning could function in a school setting, and questions included ones on their perception of students’ learning outcomes, questions on any differences they experienced between students’ questions on gender issues as well as questions on the perceived feasibility of the SESAM approach.

Interviews were recorded using a mobile phone for easier transcription. In some cases, due to a lack of video-recording permissions, the interviews were only audio-recorded. Data from observations, field notes and interviews were analyzed using an inductive approach with no predefined categories or themes. With this open approach, themes were able to crystallize and emerge from the transcribed data. The analysis took place as an iterative process, where data were read several times with the purpose of reaching a useful categorization of insights. In each round, the analyst would make notes of frequently used terms, ideas and words. These then subsequently led to the final categories and themes that structured the results section.

All schools made provision to secure approval from parents/caretakers to participate in the collection of research data in order to be able to use interviews, video and photos for research and communication purposes. Ethical approval for the SESAM programme’s data collection had been obtained beforehand from the university research ethical service department under file number 514-0173/20-5000. All data collections were done by research assistants who had signed a data-handling agreement with the principal investigator, and provisions were made to store data in an encrypted manner.

Table 2 provides an overview of the four participating schools, numbers of involved pupils, with their age and the school grade they belonged to.

### RESULTS

Over the course of the project, we managed to develop, refine and present four learning stations in a cooperation between teachers, pupils and technical mentors at our four SESAM schools. We learned that schools in general were very open to include this kind of project and themed learning in their

<table>
<thead>
<tr>
<th>Participating schools</th>
<th>Ganløse</th>
<th>Sorø</th>
<th>Herstedlund</th>
<th>Langhøj</th>
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</thead>
<tbody>
<tr>
<td>Age of about 11–15 years (fourth-, sixth- and eighth-grade) students</td>
<td>Age of about 13 years (sixth-grade) students</td>
<td>Age of about 16 years (ninth-grade) students</td>
<td>Age of about 15 years (eighth-grade) students</td>
<td></td>
</tr>
<tr>
<td>75 pupils</td>
<td>50 pupils</td>
<td>50 pupils</td>
<td>75 pupils</td>
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teaching practice. Both pupils and teachers were instrumental in opening up this kind of didactic approach. Findings from data collections (observations and interviews) have been summarized and grouped into two main themes: ‘enablers’ and ‘disablers’ for the ‘food and digital’ agenda. For enablers, we averaged factors that positively impacted the programme implementation, while for disablers we averaged factors that negatively impacted the implementation.

**Enablers**

Overall, we found that the SESAM approach to creating learning around food systems transformation in a school setting was received well. Insights from interviews and observations across the schools suggested positive attitudes, goodwill and support for the idea. The scientific and digital twist related to the programme was considered as a case for learning.

*Food systems science is more than talking – action is just as important*

Understanding the scientific and digital principles of food systems change requires understanding of both scientific principles and practical applications. We found that theory and practice interactions seemed to work well in the SESAM programme. We found that when young people had to choose between the theory and practice interactions, they tended to prefer learning interventions based on concrete action, and construction rather than traditional, theory-first types of interventions. It indicates that a higher level of involvement from young people can be achieved by using tangible set-ups such as installations, experiments, demos and workshops that the pupils themselves have prepared. During interviews, pupils expressed a view that the experimental SESAM approach was perceived as something very different from the traditional way of teaching about food at school. One of the students put that impression into words by stating:

> I also cook at home, but it’s different here because we’re doing it in a different way. This is more experimental.

This resonates well with statements from other students that they felt ‘at home’ due to the cooking theme, but that they become more engaged and motivated once they found out that this was something more than just preparing a meal. In addition, the food theme seemed to work well within the rather autonomous learning universe that the SESAM ended up creating. Some students mentioned that this way of working had contributed to a strengthening of their motivation and that they were pleased to have been allowed to work independently. And again, the ‘fun’ element – the surprise element and the experience learning components – were highlighted, which one student described as follows:

> It was also because it was not some specific food that you had to make. You decided just like yourself – it’s also a bit more fun. And it was also just something different from food than usual. This is not something you have tried before.
This approach can be seen as creating a somewhat alternative way of working with food. The pupils also mentioned that their main experiences came from home economics classes. An approach that can be described as primary skills-based, only theory driven to a limited extent and often based on a trial-and-error approach. As such, the SESAM approach can be said to stand out as being more oriented towards experiments, hypothesis building, project organizing and digital solutions.

**Events are good, but preparation is just as important**

Engaging young people in food systems issues and its digital aspects is an ambitious goal and should involve aspects of science and understanding of technology. In a busy school environment that has ‘a lot on its mind’, this is, needless to say, not something that is achieved overnight and not something that can be done without the appropriate project environment to support the effort. Most importantly, it requires time and support from both mentors and teachers with different backgrounds. We found that the potential to use the Science Night framework to organize a project provided a good framework. We learned that setting out to prepare over some months in order to be able to present something tangible and visible at the final Science Night event was an ambitious but realistic goal for schools, and we found that months of preparation became a valuable source of learning. Having a set goal of presenting the outcome at the end was a strong motivational factor. We found that for pupils to understand the digital and scientific aspects of a given food system (the learning station for this case), sufficient time for installation, planning and preparation should be given. Since the goal is highly event-oriented and includes presenting insights to others, good explanation and science communication skills are important, and training in these skills became integrated in the project along the way. We saw that pupils had very different attitudes towards the idea of presenting and being ‘onstage’. Some informants preferred to find other means of communicating their results, whereas others seemed to be ‘born actors’ and thrived in their roles as explainers. This introduced a strong element of ‘performance’ culture, which the students felt, and they learned that they were supposed to be able to present something at the final event. One of the students expressed it when his group was asked to prepare an explainer video: ‘I don’t really know, but it’s something that’s on TV, so I just hope that I have that channel. If it is Discovery then I can’t see it’.

We see this as a sign that students developed their presentation skills, and the focus on developing ‘explainers’ – small oral pitches that briefly explained the idea of the different work stations, experiments and mock-ups that the students had been working with in the preparatory phase – was strengthened.

**Food systems transformation requires understanding of nature**

Young people’s interest in food and systems change is not only related to consumption. We learned that there is an increased interest in using a broader food and agricultural environment – the ‘whole of the food system’ as the learning context. We found that a more holistic understanding of the food system needs to include understanding of nature, climate and the environment. Through observations, we found that nature and the related natural science principles offered excellent opportunities for learning about food, and we learned that the great outdoors is a well-suited learning space where youths can
experience naturally occurring science phenomena. Large numbers of 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 examined eco systems in nature water holes, etc.

Students in more of the interviews expressed the view that the adventurous part – the ‘fun’ part – was an important part of their experience of the SESAM process and that this seemed to be part of their motivation to learn more about natural science phenomena. Fermentation – being one of the new arrivals on the contemporary food scene – was one of the cases exploited in the project, and the underlying food chemistry-related pathways seemed to create new insight and at the same time a sense of experiential learning. As one participant stated: ‘The fermentation of cabbage was fun. That it [the salt] could get all the liquid out of the cabbage’.

We consider this as an underlining of the need to highlight the connections and links that exist between food processes and the underlying natural science principles, as illustrated in the following quote.

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 all at the beginning.

We also learned that understanding these principles created a good link to the sustainability aspects. For instance, understanding fermentation is a good foundation for understanding biochemical processes and cycles and, at the same time, a good foundation for understanding food shelf-life and food waste reduction potential. In general, we found a very high level of commitment and interest in schools and among teachers in working with natural science principles and nature-based solutions in relation to the SDGs and in using the principles of education for sustainability. It can obviously be taken advantage of when developing food education at school.

Engaging young people as co-creators has huge potential

Traditional innovation related to grand challenges is thought to be driven by academia and technology. We found that working with pupils at school around food systems challenges provided an excellent opportunity to create interest also at the lower stages of the educational system. We managed to set up a collaborative ecosystem that could facilitate match-making and social learning between undergraduate, graduate and postgraduate students, together with mentors from start-ups and private enterprises for the development of installations at the schools. We experienced that involving young people as co-creators of the SESAM event both in the development of installations and in the awareness raising for the events 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. For instance, bringing graduate students who know about how to build a vertical farming installation, such as an aquaponics facility, provides plenty of opportunity for vicarious learning and role modeling. We found that young people
are more digital-friendly and were easily able to find information if proper guidance was provided. For some of the installations, the students co-created with the involvement of mentors to inspire the work. As such, the mentoring approach became an important element of the work. This ended up in the creation of small co-creative learning spaces at the schools, where technical mentors from small food start-ups, organizations and university supported the preparatory work at schools. In some cases, teachers acted as facilitators, and in other cases, mentors simply joined the student groups directly. As such, the work created an important platform for co-creating food solutions and installations, and students on several occasions expressed the view that the modeling and vicarious learning outcome was important and a good source of inspiration for them.

It was really exciting to have somebody coming from outside to challenge us. I mean tell us about food waste you know. But also that they could show us ‘how to’. Everything gets a little more exciting when somebody just come from outside.

We consider this as an interest in a type of open school approach and citizen science in the classroom that resonates well with the schools’ interest in cooperating not only with university partners but also with experts and professionals from private companies and small start-ups. In general, we found interest across the group of teachers and among students, and we see this as a clear indication of the fact that working with food issues and topics in a scientific, technological and digital framing, which is the case in SESAM, obviously introduces a need for co-creating solutions in a kind of knowledge triangle configuration where education, market and research are represented.

**Schools welcome the science and digital agenda with open arms**

In knowledge-intensive societies, it comes as no surprise that there is an intense interest in using the infrastructure of the educational system to promote research and scientific thinking. In particular, STEM is in focus because of its potential impact on the economy. We learned that elementary schools are highly welcoming when it comes to the digital agenda. We observed and learned through the rounds of data collection that STEM learning, twenty-first-century skills and technology understanding are topics that rank highly in the school agenda. The action- and experimental-focused approach of the programme seemed to resonate well among students. As one of the observers’ notes explained: ‘Both girls agree that they love to do experiments, they say, and that was precisely why they chose SESAM. The boy comes back, and all three agree that science is really fun’.

This demonstrated a general openness and interest in the idea of education for sustainability and integrating the SDGs into the learning and curricular activities. In particular, the digital and food systems-oriented agenda of the project was welcomed by teachers as an interesting and well-suited component in the teaching of computational thinking. In the words of one of the SESAM teachers:

I think the purpose is for those students who do not like natural science and to get them up, but I think for those who already liked it, it has just been a better way to teach.
I’m pretty sure that this can help to change people’s point of view and give them new ideas about what they can be in the future. Perhaps they will be something within science.

Using STEM, science and digital as conceptual foundations for the programme proved to be of high importance, both in the negotiation and in the implementation phase. We experienced a high degree of resonance both at the headmaster’s and at teachers’ level. And among pupils, we found that the younger generation quickly becomes digitally literate and able to handle both data and digital devices, and that they learned to find relevant information if proper guidance was provided. We learned that engaging not only home economics teachers – who obviously would already have food on their subject list – but also teachers with biology, math, physics, chemistry and computational thinking as their subjects added a whole new and cross-disciplinary dynamic. Through the teachers’ enthusiasm for the natural sciences, as they have presented in the preliminary experiments, they have formed the basis for the subsequent project work.

**Disablers**

Although we found much positivity, goodwill and support for the idea of using food systems transformation with a digital twist as a learning case at school, we also identified a number of barriers and hindrances for the implementation of this kind of advanced food systems education at school.

**Everybody wants to make friends with schools**

Schools play a central role in forming and educating the citizens of tomorrow’s societies for a future entangled in a long range of grand challenges. Social inequality, urban crises, unhealthy lifestyles and disorders, anti-democratic movements and climate change are just some of the threats to our common future and all issues that schools are expected to relate to. And obviously, there is a limit as to how many of these societal agendas a school can handle and treat in their learning activities. This research found many signs of fatigue in the attitude among teachers and headmasters, who expressed the view that they felt both overloaded with demands and expectations from the surrounding societies, and frustrated with the range of constraints they felt in terms of lack of time and resources. From the interviews, it is clearly reflected that in general there is a lot of interest from a range of stakeholders in society to work with schools, but there are a range of societal challenges where it is believed that schools and young people are a good place to start. We learned, in particular during the recruitment process, that headmasters and teachers from time to time feel overwhelmed by the expectations from the outside. So, although most schools support the idea that society should reach out to the school – and vice versa – they also advocate for a more ‘disciplined’ approach from actors from outside, such as SESAM team members. This is in particular related to the fact that schools work at a different pace and in a different mode compared to universities and outside organizations. As one of the teachers expressed it:

I would like to see the connection between the university and the schools improved. It became too flighty to sit colleagues who were pretty frustrated with it. There was a lack of a structured intermediary.
We see from here that working in an open school mode and trying to apply the knowledge triangle in practice requires a structured approach and good command and understanding of the school ethos among the actors who want to ‘make friends with schools’.

**Schools are low in project literacy**

Taking into account the fact of how much organizational life nowadays is organized in projects and how much effort is directed to the organizing of innovation and change under a project umbrella, it is important to notice that, according to our findings, schools are used to working in a routine mode and less in a project mode. We found plenty of evidence in our data that revealed a lack of knowhow on how to engage in projects with external partners such as mentoring parties and universities. We found that schools in most cases had agreed priorities towards open school 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. In some cases, it went well, as one of the teachers described: ‘We just did something in the unknown, and hoped that it would hit the spot’.

In other cases, it became clear that setting up a good frame for the process was dependent on a well-defined project infrastructure. From the interviews with teachers, it became clear that working in a project mode was new to many of them, and this ‘projectification’ of school life was not ideal for everyone.

Teachers generally described how they lacked an administrative intermediary at the schools who could be responsible for communication between the university and the school. More of the teachers found that the preparatory phase at the schools, with the SESAM learning themes in the back of their minds, was a bit too hectic to complete the project, as there was no structured communication.

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.

In general, this type of comment points to a general potential conflict that exists between teachers and change agents – such as food systems change-makers like the SESAM team. We conclude that for food systems education projects at school to fully succeed, there needs to be alignment between project partners and there needs to be good and firm project infrastructure available.

**Teachers face a vacuum in terms of digital competences**

Working with sensors, microcomputers, robots and other kinds of digital devices to create concrete and tangible installations that can contribute to food systems transformation thinking makes digital literacy a crucial component in developing the SESAM-style learning activities. Our interviews and observations showed many examples where participants and teachers were caught in problems sorting out technical challenges related to lack of interconnectivity, missing operational procedures, lack of data storage capacity, missing user instructions and, most importantly, lack of technical insight, knowledge, skills and competencies. It was clear from many of the teacher interviews that working in the SESAM mode and with a clear focus on the STEM principles...
introduced a more research-oriented way of teaching and that this approach was found to be challenging in some cases, as stated by a teacher:

It’s just really hard to have to work inside this STEM and project-based way because it’s becoming very intangible in relation to methods and in reality, 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 no time for that.

Some teachers found the facilitation process difficult and demanded that specific teaching material was prepared. According to the teachers, these needed first to be ‘translated’ from the academic into practitioner language in accordance with the teaching requirements and processes that teachers are used to. Some teachers complained that they did not have time to translate voluminous academic knowledge into specific teaching materials while at the same time facilitating a major project. A teacher phrased this slight frustration in the following manner: ‘If I’m better equipped and the focus and framework for the project is taken up more sharply, the project will have a huge potential’.

**Schools are not used to working in a project-based manner**

Traditionally, schools work within a curricular framework, where core subjects have not changed much over the past century. This has tended to create a kind of silo thinking in which instructors have developed teaching that fits with the nationally decided curriculum learning goals. However, in a transversal kind of thinking, where learning is created around multidisciplinary themes, such as digitally driven food systems transformation, a different approach is needed. It requires teachers to apply knowledge in a transversal manner from different fields such as biology, math, chemistry, physics, technology understanding and computational thinking. We found that combining traditional school-fixed curriculum subjects with a horizontal way of thinking across subjects created significant challenges and tensions among the teachers. We see this as a general challenge that exists in many cross-profession collaborations. But in a school context, it becomes a specific challenge that is related to the PBL approach itself. This mode is different and obviously requires skills both among teachers and students, and on many occasions, we observed confusion on how to get the most out of the project-based teaching. For instance, 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 had arranged for themselves to be in the back row of the room, which both gives rise to independence but at the same time with help from the teacher within reach. The students distributed the tasks between themselves and were found to be working patiently and in a structured manner towards their goal of making a yogurt-based recipe that they subsequently added to mashed fruit and sugar while at the same time trying to add the data capture feature to the mock-up. The group generally worked independently without much supervision from the teachers, but nevertheless, the PBL framework in some cases gave rise to some challenges and disagreements along the way. As one student explained it: ‘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’.
Overall, we found much support and liking of the SESAM approach among both teachers and pupils. However, we also from time to time saw some weaknesses related to the idea that pupils had to work on their own, on their own projects, on topics they have chosen themselves and in a mode where teachers were supposed to stay in the background and intervene on-demand only.

**DISCUSSION**

We argue that a sustainable transformation of the food system requires engagement and capacity-building at more levels and that digital understanding and future-ready skills among young citizens in a broad sense are essential. This study clearly shows that using the food system and the call for sustainable transformation can be a powerful learning platform. It holds the potential to create engagement in the learning process and an interest in understanding underlying natural science principles. In particular, we learned that students are not traditionally attracted by STEM principles, so science and digital topics became more engaging due to its focus on the everyday life perspective of food and eating. We learned that bringing in new digital technologies such as robotics, AI, machine learning and IoT, and applying them to tangible and concrete tasks related to food and growing, tended to counteract alienation and make science more relatable in the eyes of the students.

We found the beginnings of a new mobilization of young people when it comes to questions and issues that are critical in a climate context. Our study showed clearly that young people know how important it is to take action towards protecting the environment, and new generations are becoming more and more concerned about the emergencies of not only the state of the climate but also the state of biodiversity, the soil and marine resources, as well as food and agricultural issues. During the progress of the project, we saw clear signs that young people increasingly see themselves as having the right to speak up in matters that affect their future.

Digitalization and food systems change are relevant for young people in a different and new way since the topic is deeply rooted in the question of climate change. We learned that the climate crisis has attracted the interest of young people in a completely new way. This also means that the traditional evidence and ‘right to speak’ hierarchy of the knowledge society is increasingly challenged by young people. We learned that communicating science and bringing in the technical knowledge needed to understand innovation and digitalization in the context of learning and teaching at school is very dependent on using ‘age appropriate’ role models and on using youth-specific communication channels. Although science and research are traditionally overrepresented by senior researchers, we learned that it is important to prioritize bringing in early career researchers who can act as vicarious learning models and add impact.

Compared to traditional themed approaches to creating learning and engagement around scientific, technological and digital topics, we learned that using the ‘edible’ and ‘feeding hungry world’ seemed very effective. We also learned that bringing in concrete and down-to-earth examples and cases has the opportunity to cater for the interest of girls who tend to leave the floor too much to boys when science and tech subjects are brought to the classroom. We were able to build further on the inclusiveness of the
tangible and familiar ‘feeding the world’ theme to increase the impact of the NIGHT objectives by attracting more young people, and our results showed that we attracted more girls and more students not normally attracted by STEM subjects.

Generation Climate is more environmentally conscious than previous ones (Petro 2020) and tends to practise a more sustainable lifestyle. This creates an opportunity to connect SESAM’s goal of inspiring more pupils to pursue science and our education’s goal of training individuals to be more conscious in their lifestyle choices in a single event, centred around learning practical skills. For the didactic aspects it became clear that working in a solution-oriented fashion offers advantages, since it tends to attract other types of pupils than those traditionally interested in science and digital subjects.

CONCLUSIONS
Overall, we found that – under the right circumstances and supportive project environments – it is possible to assign young people at school a role and a voice in the efforts to induce food systems transformation – and to include an important digital component in these efforts. The results from the programme showed that, overall, students improved their understanding of sustainability and the role of science and digitalization in food systems change. It clearly showed that developing tangible mock-ups, installations and demonstration cases based on student-driven action and construction created two important outcomes – individual learning for the students, and salient and easy-to-understand examples of how science and design thinking, combined with digital insight, can provide new solutions of value in food systems change.

The result clearly showed that students benefitted greatly from the practice-based teaching and from seeing the transfer of theory to practice in their work with installations, labs and workshops. The findings also showed that students benefitted greatly from the SESAM excursions, site visits and the direct interactions with the technical mentors who we used to construct the installations and learning stations.

We found that working with schools has a high degree of visibility due to the central and recognized role that schools play in local communities, as pupils are part of families and social networks. The high degree of local media exposure, and the wealth of communication that the schools had with families, was very helpful for the exposure of the programme. The SESAM approach also gained wider potential to act as a lever of citizen engagement in food systems change. From interviews, we learned however that pupils involved their families both during the preparatory phase and in the final execution of the event.

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SUGGESTED CITATION

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