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S.I. : TRANSFORMATIVE LEARNING FOR URBAN SUSTAINABILITY

Climate Garden 2085: An easily applicable transdisciplinary public art-science experiment for transformative learning about climate change

Juanita Schlaepfer-Miller[1] · **Christoph Kueffer**[2] · **Manuela Dahinden**[1]

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Abstract
Climate change education is inherently part of Education for Sustainable Development which has manifold aims to develop transformative learning from primary to tertiary pupils. Climate change is challenging as a school subject, as although it can improve pupils' knowledge, it is less evident how such knowledge translates into decreasing the value-action gap. Climate change also transverses disciplinary boundaries and teachers struggle to incorporate it into the curriculum. We present a transdisciplinary art-science public experiment—the *Climate Garden 2085*, as a methodology which has proved a popular tool for schools to engage their pupils with climate change and sustainability. The *Climate Garden 2085* is a participatory art-science work that engages school pupils as social groups, and in emotional ways with scientific questions related to the effects of climate change on plant species that are important for food production and gardening. Greenhouses simulating different climate change scenarios engage pupils in a tangible way with climate change effects on plants while accompanying plant science and art workshops allow them to carry out hands on experiments. The garden art-science intervention has so far been created 24 times, with more than 100 workshops, and reached around 40,000 people. It continues to attract major interest by teachers and schools. Based on qualitative observation and some quantitative data, we discuss possible reasons for the attractiveness of the methodology for schools and explore how it might affect awareness and behavioral changes of participants. We propose that the poetic nature of a garden and the length of engagement that the garden affords, combined with the embodied experience and time and place for discussions, has great potential for enabling reflection and action toward climate friendly and sustainable urban futures. We present the project here in order to encourage others to create their own *Climate Garden*.

Keywords Art-science · Climate change education · Climate garden · Sustainable development · Transformative learning

✉ Juanita Schlaepfer-Miller
juanita.schlaepfer@usys.ethz.ch

[1] Zurich-Basel Plant Science Center, Tannenstrasse 1, 8092 Zurich, Switzerland

[2] Department of Environmental Systems Science, ETH Zurich, Switzerland and Eastern Switzerland University of Applied Sciences, Rapperswil, Switzerland

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1 Introduction

We present in this article a participatory art-science public experiment—the *Climate Garden 2085*, as a methodology to engage school pupils with climate change and sustainability. We wish to add to the growing number of innovative educational initiatives by illustrating how art-science experiments are one way to better engage pupils on an affective learning level (attitude and emotion) rather than the realm of cognitive understanding which is often the focus of science education (Friedman, 2013). The *Climate Garden 2085* brings together not just the disciplines of natural science and art, but theory and practice of education for sustainable development. It was originally conceived as an art-science education experiment in an out of school learning setting, to address the "wicked problem of climate change" but is now increasingly finding a place in the education system (Schläpfer-Miller, 2021). From 2016 to 2022 it has been installed (each time for 3–6 months) in small to large cities in Switzerland and USA—Zurich, Berne, Rapperswil and San Francisco—as well as in fifteen high schools and four vocational colleges and a public garden run by a foundation (23 in total). Four of the participating high schools have a permanent installation.

1.1 Climate change education—an integral part of education for sustainable development

With the United Nations Decade of Education for Sustainable Development (2005–2014) learning for sustainability gained increasing attention. The UN has for instance helped to develop a global network of so-called Regional Centers of Expertise on Education for Sustainable Development (RCEs, https://www.rcenetwork.org/portal/). For universities, there are initiatives such as ProSPER.Net (https://prospernet.ias.unu.edu/) and in Europe the Copernicus Alliance (https://www.copernicus-alliance.org/). Climate change education is inherently part of Education for Sustainable Development (ESD). To reach the UN's climate goals, a strengthening of targeted research, teaching and policy dialog is not only of relevance to the climate sciences or energy research, but to all disciplines including the plant sciences, as demonstrated in this article.

Climate change education is deemed an essential part of current education from primary schools to universities. Climate change is challenging as a school subject, as although it can improve pupils' knowledge, it is less evident how such knowledge translates into decreasing the value-action gap. A meta-study of climate change education events found little evidence of sustained positive effects once an intervention had ended (Nisa et al., 2019). Furthermore, schools struggle to incorporate complex climate change studies in the curriculum as it transverses disciplinary (school subject) boundaries (Oversby, 2015). Pupils should experience transformative learning in order to engage in more climate-neutral practices. Yet what kind of intervention or learning experience, and for how long, is an open question. How to promote enduring change is challenging. It has been suggested that what is required is "deep engagement, general mental models and social norms" (Goldberg et al., 2020). The authors postulate; "persuasion via deep processing is more likely to lead to enduring attitude change."

Thus, climate change education as part of ESD has multiple aims to develop diverse environmental competences of primary and secondary school pupils as well as students. For instance, the climate-related learning goals defined in the Swiss national curriculum (édcation21, 2013), which are in turn based on the DeSeCo–Definition and Selection

of Competencies (Stephens et al., 2003) state that education should, besides disciplinary knowledge, focus on interdisciplinary- and multi-perspective knowledge and lateral thinking. Accordingly, action-oriented, transformative didactics are required (Rieckmann, 2021). Transformative learning aims at social competences and a strengthening of individual agency: the abilities to change perspective, cooperate and participate in social processes, as well as virtues such as responsibility, reflexivity, and action-orientation. An important focus is thus on increasing the ability to engage with transformative processes. The hope is that from transformative experiences of individuals social processes emerge: "Transformation arises from small germ cells that have to be sown and then will grow" (Welzer, 2019) (translated from German). Transformative learning can be entertaining, i.e., it can combine "enter education, infotainment and edutainment" to incorporate educational messages into popular entertainment to encourage empowerment, conservation behavior and increasing dialog with family and friends (Flora, 2014). Transformative learning is positioned in a broader context of "transformative reflection and communication," i.e., of approaches that consider people's inner lives, in order to address socioecological crises through individual and cultural transformation (Fraude et al., 2021). For instance, by creating experimental spaces at climate conferences (*COP25* in Madrid in 2019, the *K3 Congress on climate change, communication and society* held in Karlsruhe in 2019, and a symposium on *How to move from climate knowledge to climate action* held in Bremerhaven in 2020) the research group from the *Institute for Advanced Sustainability Studies e.V. (IASS)* was able to facilitate a variety of safe spaces—from dialog circles to yoga—which shifted science communication to engage with peoples' beliefs, worldviews and motivations. They outline several design principles and facilitation recommendations which could be adopted by those interested in deepening engagement of their communication target group (Fraude et al., 2021). There is evidence that the kind of learning that the latter project affords has a positive effect on critical thinking, motivation, and behavioral change (Gómez & Suárez, 2020).

The hope is also that transformative learning in schools reaches further into society. A potential ripple effect of school climate change education has been noted by several authors as children function as influencers within their families, promoting environmental stewardship behavior and correcting misperceptions (Weilminster, 2014), (Trott et al., 2020), (Timmis et al., 2020). Adolescents may be viewed as non-threatening storytellers, as for example, in an inspiring nine-year action, the *Cool Science* project in Lowell, MA, USA, where youth artwork about climate change was displayed on public buses (Hendrickson Lohmeier et al., 2021). Also important for transformative learning are trainees in vocational schools. There are a great number of professions which are affected by climate change mitigation and adaptation including transport, agriculture, logistics, construction, nutrition, commerce, city-planning and management. Reaching trainees in these professions through vocational training is considered a crucial national sustainability mission in Switzerland (BAFU, 2020). Further, schools are institutions embedded in their neighborhoods where they can have broader impacts on society. Local places, and especially densely populated urban areas, e.g. (Barber, 2013), (Kueffer, 2020), are considered important innovation hubs of societal change.

1.2 Zurich-Basel plant science center—a boundary organization

In this article we present a transformative learning project—*Climate Garden 2085*—that is led by a boundary organization institutionalized across several universities in Zurich and Basel (Switzerland): the Zurich-Basel Plant Science Center (PSC).[1] Boundary organizations are institutional arrangements that aim at enabling continuous co-production of knowledge and mutual learning at the science-society interface (McGregor, 2017), (Posner & Cvitanovic, 2019). They promote transdisciplinarity through close and reciprocal knowledge production and consumption processes at the boundaries between basic and applied research and society (Kueffer et al., 2012), (Cash et al., 2003). The PSC supports educational outreach and inter- and transdisciplinary research in the plant sciences, among others by funding PhD programs in Science and Policy and industry-partnered fellowships.[2] *Climate Garden 2085* is one of several of PSC's creative science education projects. *Dialog in Quartier* is another project of the PSC which organizes workshops and dialog formats in community centers and supermarkets in Zurich and Basel, engaging different publics in discussions on: "How can households change their eating habits so that these systems are supported? Which competencies and skills must be available in a household or a community in order to support sustainable eating habits? What does it take for a resilient, local, diverse, and fair food system, which offers everyone access to sustainably produced and healthy food, to emerge and sustain itself?"[3] Given the focus of the PSC on plant sciences, many educational and outreach activities focus on sustainable food. Partially attributable to the Corona crisis, the population's awareness of local, sustainable food supply and production has increased. The number of vegetable subscriptions from local suppliers (community supported agriculture), while previously declining, increased during the pandemic (Seo & Hudson, 2022). Direct marketing is booming, delivery services for local products are in demand and neighborhood distribution systems are trying to maintain alternatives to the supermarket. In reality, it is difficult to change the diet within a household (Irz et al., 2019). These are some of the specific questions that *Climate Garden 2085* also addresses.

1.3 Art-science public experimental spaces

The *Climate Garden 2085* project aims to enable transformative learning about climate change and sustainability, especially among young people in urban areas. It is inspired by the field of participatory art-science which rejected modernist goals of objectivity and individualism and attempted instead to create new categories of knowledge, more akin to transdisciplinary research and citizen science (Billing, 2007), (Bishop, 2012), (Dews, 2002). According to Vega (Vega et al., 2021) "Participatory art-science is a strategy of engaging citizens focusing on the social and emotional aspects of knowledge production". Using terms such as "public experiment" (Barry & Born, 2013), an artwork might use the structures and methods of science to create an embodied aesthetic experience (Alexander & Dewey, 1987). Art historian Grant Kester sees this as symptomatic of shifts in art, one,

[1] https://www.plantsciences.uzh.ch/en.html
[2] https://www.plantsciences.uzh.ch/en/research/fellowships.html
[3] https://deinquartiernachhaltig.org

towards participation and the other away from presenting the viewer with a text or object (Kester, 2011).

In his essay *The Art of Disciplined Imagination*, Theo Reeves-Evison compares the *Climate Garden 2085* to other "speculative infrastructures" such as the early cybernetic works of the group Experiments in Art and Technology (EAT)[4] (La Prade, 2002), from artists Roy Ascott and Stephen Willats, which he describes as artworks which use "material forms to meditate infrastructures and bring them to the representational surface of the artwork." (Reeves-Evison, 2021) p. 722). The EAT artwork *Utopia Q&A* and Willats' *Speculative Modeling with Diagrams* brought post-cold-war predictive thinking to the gallery for public consideration. What is different about the *Climate Garden 2085* is that it allows consideration of multiple futures (Reeves-Evison, 2021), p. 723). The art critic Meredith Miller refers to "speculative cultural practice" as an "alternative to the abstracting tendencies of data-focused [ones]" (Miller, 2016) p. 21). Thus, "the 'artistic strategy' of the *Climate Garden 2085* is to offer the audience participants a way to develop an understanding of climate scenarios through physical perception by presenting the climate scenarios in an experiential form" (Schläpfer-Miller & Dahinden, 2017) p. 11). Further, it engages the public in research practices comparable to citizen science projects. Indeed, there is an increasing awareness that citizens should be able to participate in science, as stakeholders, data gatherers, or as lay experts (Dickinson et al., 2012), (Silvertown, 2009).

An important dimension of the *Climate Garden 2085* is that it uses a garden setting as immersive learning environment. Gardening has long been considered an individual and social activity that supports ESD by nurturing virtues such as cooperation, responsibility, or care (Stuart-Smith, 2021), (Krasny & Tidball, 2015), (Cooper, 2006). The garden environment connects to ecology, an important pillar of any climate change adaptation, and embeds learning in the natural rhythms of nature: "Nothing is more obvious in a garden than change" (Miller, 2010) p. 178).

2 The *Climate Garden 2085* methodology

The *Climate Garden 2085* comprises two greenhouses each based on a climate scenario specifically downscaled for different regions of Switzerland (CH, 2018, 2018) and planted with rows of fruits, vegetables and flowers chosen by the school classes. In preparation for the garden the pupils discussed their vegetable eating habits, and accordingly which plants they would like to grow. This mixture of plants includes both climate winners, such as soybean, and losers, such as wheat and potatoes. A common type of greenhouse often found in local allotments and gardens is used to provide a familiar visual scenography. The average monthly summer temperatures in one greenhouse represent an emissions control scenario and in the other the 'business as usual' scenario, both for 2085. This date was chosen as being within the lifespan of younger visitors. To simplify communication, we described them as '+3 °C' and '+6 °C'. The precipitation scenario for 2085 suggests a reduction of

[4] Experiments in Art and Technology (EAT) was founded in 1967 by Julie Martin, an arts administrator, with Billy Klüver, an electrical engineer working for Bell laboratories, the engineer Fred Waldhauer, and artists Robert Rauschenberg and Robert Whitman with the goal of encouraging collaborations between art and technology.

Fig. 1 A school group in the Climate Garden 2085 in the Old Botanical Garden, Zurich 2016 (J. Schlaepfer)

8–28%. Extreme summer drying was modelled by giving one row of plants in each greenhouse 30% less water. Air humidity was 40–60%.

In addition to the plant experiments that the pupils devised themselves, at each school the PSC carried out workshops with the school classes. These comprised for instance, gas exchange measurements with abiotic stressed plants: Three sets of plants (e.g., beans, maize, and pumpkin) were grown in each greenhouse and subjected to a drought or flood stress for four days before the workshop. The third group was a control. The gas exchange of the plants was measured in three ways with a CO_2 meter, a porometer which measures stomatal conductance, and a technique to visualize the open/closed state of the stomata using nail polish. Another workshop involved a staining of mycorrhiza in plants which the pupils had inoculated themselves with mycorrhiza spores.[5] Each workshop was followed by a discussion and reflection on the experiments and their implications for plant cultivation under climate change. There was also space given for discussion of personal, societal, and political measures against climate change. The workshops were run by PSC doctoral or post-docs in plant sciences who brought the measuring devices with them to the school. Using the plants prepared by the school a 3–4 h experiment and discussion took place in a school classroom or outside the *Climate Garden* itself. (Figs. 1 and 2). Additionally, two of the four vocational colleges participated in a third workshop on the theme of food sustainability. This workshop "Teller der Zukunft" (My future diet) asked: What are the effects of diet on planetary boundaries? What options does each individual have to halve these negative environmental impacts through diet? The art workshops included monoprint making with cyanotype, and other printing techniques. The "Plant Blindness" workshop developed by an art education student encouraged participants to think about whether they really *saw* and *noticed* plants. They then, in a group activity, created collages of fantasy plants.

[5] Instructions for these workshops are open source and available in German: https://klimagarten.ethz.ch/angebote-fuer-die-oberstufe/.

Fig. 2 Pupils engaged in plant stress experiments in Zurich in 2019 (J. Schlaepfer)

The plants used in the experiment are agricultural and horticultural, to impact the way participants think about both their food systems and urban landscapes, for instance by comparing current and future food supply. By creating their own plant ecology and physiology experiments, participants are encouraged to connect present day activities with future outcomes, a transformative endeavor to change food consumption and contribute to dialog on the quality and function of our urban landscape in a time of crisis. The concept of dialog is critical as it invites engagement between the sciences, climate change, food, and urban systems. The idea is not primarily that people understand that their food might not grow as well in a few decades, but rather to make them think about how information from the sciences matters to their decisions, and what they want their food supply chain to look like in the future.

The workshops on food sustainability carried out by the PSC within the framework of the climate gardens discussed such questions with participants. Pertinent, difficult questions were raised, such as "Is it enough to realize utopias in the private and small-scale, when many have the feeling that the big picture is not right?". We reflected with participants on any transformation in collective or individual agency post-*Climate Garden*. Such as energy saving or consumer behavior, and if they felt more informed and able to share information with friends and family.

In total, *Climate Garden 2085* has so far been created 24 times, with more than 100 workshops, and reaching around 40,000 people (Table 1). Each school was required to invite surrounding primary schools to visit the garden, and the high school pupils gave the younger pupils a tour. In addition, each school was expected to put on a public or community event and again have the high school pupils explain the project. The schools also wrote a blog post for the Climate Garden website available at: https://klimagarten.ethz.ch/en/blog/

3 Evaluation of *Climate Garden 2085*

In 2021, we evaluated the Climate Garden 2085 experiments with a survey. School pupils answered an online questionnaire before (pre) the *Climate Garden 2085* installation, and after (post). We present data from two schools, a vocational school (BSA) and one

Table 1 List of Climate Gardens 2016–2023. The visitor numbers include participants in the workshops we gave, unless the schools reported their additional visitor numbers. At each school other classes not directly involved also visited the garden and were given tours by their peers. This would add at least a hundred visitors to each school participant numbers

List of Climate Gardens in schools and public exhibitions 2016–2023			
	Pupils level/age	Visitors and/or Workshop participants	Type of activity
2023			
Berufsschule Arenenberg	Vocational School 16–20	598	Workshops and Open Day
2022			
Kantonsschule Zug	High School 12–18	21	Workshops
Kantonsschule Uetikon am See	High School 12–18	21	Workshops
Berufsschule Mode und Gestaltung, Zürich,	Vocational School 16–19	248	Workshops
Bildungsdepartement bzb Rheinhof, Salez	Vocational School 16–20	45	Workshops
Anna Zemp Stiftung, Männedorf	General public	150	Workshops & public tours
2021			
Kantonsschule Rychenberg, Winterthur	High School 12–18	20	Workshops
Institut auf dem Rosenberg, St. Gallen	Boarding School 5–19	12	Teacher workshop
Gymnasium Kirschgarten, Basel	High School 12–18	46	Workshops
Gymnasium, Wirtschaftsmittelschule Thun	High School 12–19	22	Workshops
Berufsschule Aarau	Vocational School 16–19	26	Workshops
Kantonsschule Menzingen	High School 12–18	19	Workshops
LBBZ Schluechthof Cham	Vocational School 16–19	0	Figure not available
Anna Zemp Stiftung, Männedorf	General public	150	PUBLIC tours
Amt für Landwirtschaft und Natur Inforama, Zollikofen	Vocational School 16–19	0	Figure not available
Kantonsschule Schaffhausen	High School 12–18	1	1 high school thesis
2020			
Kantonsschule Rychenberg, Winterthur	High School 12–18	0	COVID
Institut auf dem Rosenberg, St Gallen	Boarding School 5–19	15	Tinkering Workshop
Kantonsschule Wettingen	High School 12–18	50	High school thesis, Talks

Table 1 (continued)

List of Climate Gardens in schools and public exhibitions 2016–2023			
	Pupils level/age	Visitors and/or Workshop participants	Type of activity
Gymnasium Muttenz	High School 12–18	0	COVID
2019			
OST Rapperswil, Technical University, Rapperswil	Technical University 16–25	15,000	Workshops & public tours
Gymnasium Muttenz	High School 12–18	270	Workshops
Evangelische Mittelschule, Schiers	High School 12–18	280	Workshops
Kantonsschule Limmattal, Urdorf	High School 12–18	250	Workshops
Kantonsschule Wettingen	High School 12–18	140	Workshops
Kantonsschule Unterstrass, Zürich	High School 12–18	1000	Workshops & public tours
2017			
Swissnex, San Francisco, California, USA	General public	2500	Public tours
Botanische Garten, Bern, Switzerland	General public	10,000	Workshops & public tours
2016			
Alte Botanische Garten, Zürich, Switzerland	General public	10,000	Workshops & public tours
Total number of Climate Gardens 24	TOTAL visitors	**40,884**	

gymnasium (GK). The survey was answered by 89 GK pupils pre and 39 post, and 47 BSA pre and 12 post. Pupils were aged 15–19. The high schools are called Gymnasium in Switzerland and correlate to the old grammar school system of the UK, teaching university preparatory classes. The GK high school was in an urban area. The vocational school was in a peri-urban area and taught agriculture and horticulture. The online survey link (using surveymonkey.com) was given by the teachers and lesson time was provided to complete them. We account for the dearth of post responses in that it was summer, and after exams many classes do not meet again. We sent numerous reminders to the teachers, again in the autumn semester but some of the pupils had left school already.

The data were analyzed by comparing the pre and post surveys and looking for trends. It is not possible to report statistically robust results as the post survey had only a quarter of the respondents of the pre-survey. We aimed to identify trends in the post survey responses, but these must be seen as qualitative rather than quantitative data. As there were no personal identification numbers on the surveys, we were only able to sort the surveys according to school and not respondent.

The pre- and post-surveys asked the same or very similar questions. There was room for some open-ended answers. We evaluated the following questions which we have translated from German (Table 2 summary, complete list in Appendix).

For the analysis, the diverse answers of the students we grouped into five categories. We were more specifically interested in their attitudes toward local and seasonal foods.

The questions were based on the "Education for a Sustainable Future" (Bildung für Nachhaltige Entwicklung BNE) from the Swiss School Curriculum21 (éducation21, 2013). These climate-related learning goals are based on the oecd.org future skills goals (Organization for Economic Co-operation & Development, 2018) The plots were created using RStudio and the ggplot2 package.

4 Results

We present the results from selected questions in two parts. Part one, a comparison of selected questions pre- and post garden as percentage of respondents, however as stated above these must be seen as trends and not statistically relevant. Part two presents qualitative responses.

Table 2 Main question themes and example questions

Main Question themes	Example questions
What is climate friendly consumer behavior	What do you consider to be the most important factors to combat climate change?
	Are local and seasonal foods important to you? Do you eat local and seasonal produce?
	Have you eaten more local and seasonally? (since the Climate Garden)
Factual knowledge about plants and climate change	Global warming will make it possible to grow new crops in Switzerland. Do you know such plants (climate winners)?
	Do you know plants that can no longer be grown (climate losers)?
Awareness of plants and climate change	Did the Climate Garden make you more aware of climate change and plants?

4.1 Behavioral changes

The results indicate that the participation in the *Climate Garden 2085* promoted thinking and behavioral change in relation to food consumption (less meat, local and no food waste), while there was a tendency of decreased importance given to other actions ('no fly/oil/petrol', and 'social/political') When asked if they thought eating locally produced food was important, and if they actually did eat local food, we saw a tendency in both schools to an increased awareness and practice of eating locally produced food. Because the return rate of questionnaires was substantially lower in the post evaluation, it cannot be said to what extent students changed their attitudes or the results were biased by the correlation between attitudes and preparedness to respond to the questionnaire. What can be said, though is that the absolute number of students with positive attitudes toward local and season food *and* enough commitment to respond to the questionnaire increased (Figs. 3 and 4).

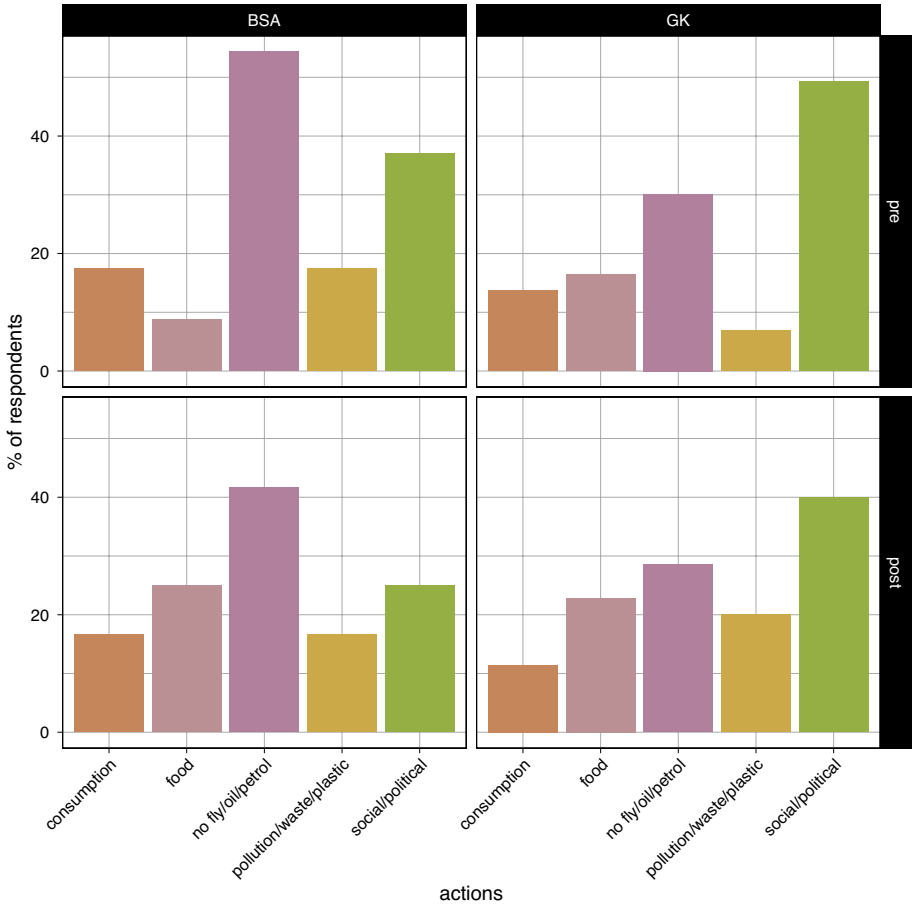

Fig. 3 Responses to question: What are the most important factors to combat climate change? BSA is a vocational college and GK a high school. The response field was open-ended, and we bundled the categories

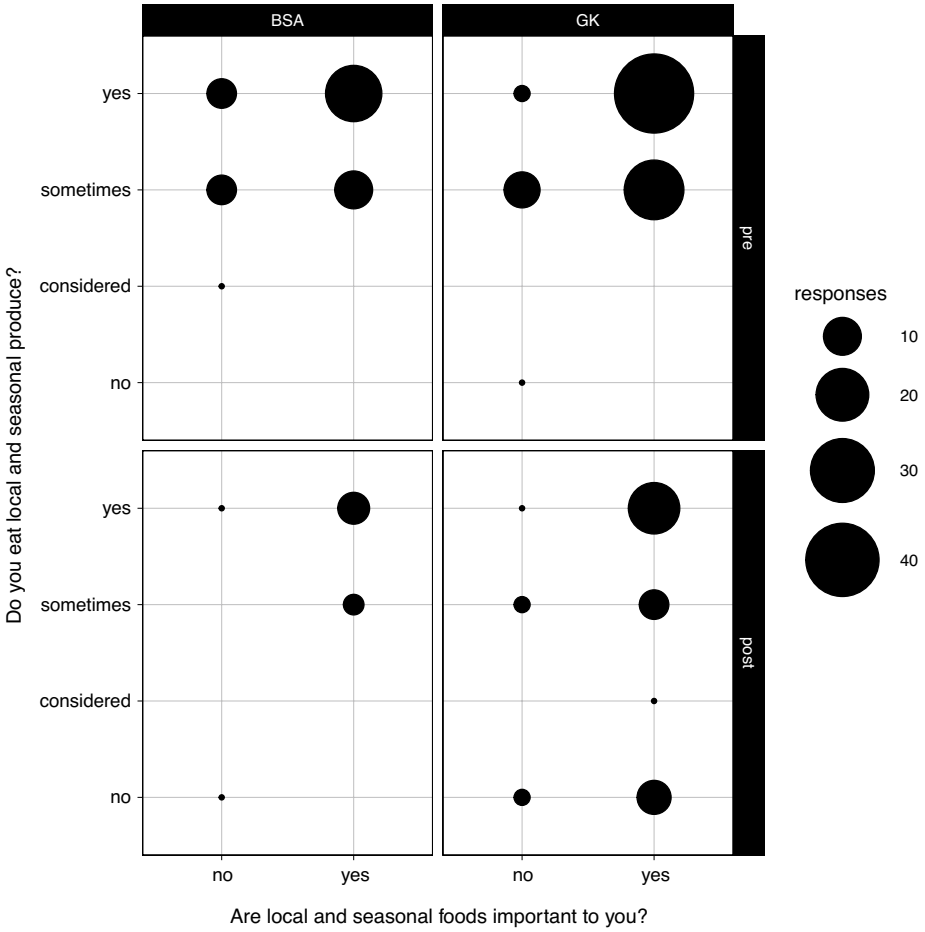

Fig. 4 Two questions were compared "Is eating local and seasonal important to you?" And "Do you eat local and seasonal produce?" In the post survey the question was "Do you eat more locally and seasonally since the Climate Garden?"

Factual knowledge gained as tested post *Climate Garden 2085*, was an ability to name plants which would be climate winners and climate losers (Figs. 5, 6, 7 and 8). In the pre-survey the overwhelming response from the high school pupils was no, they could not name a plant that was a climate loser, and they only made a few guesses. The vocational school pupils could answer this more correctly. They were from a school specializing in agriculture and horticulture and so this would be expected. It should be noted that this is also a difficult question, as corn is a climate winner in terms of temperature, but only if it has enough water. In the post survey, the number of plant species named increased substantially. The pupils learned to differentiate between 'climate losers' and 'climate winners', and they realized while some plants would survive, we would have to change our eating habits. That the factual knowledge about plants and the effects of climate change on plants was enriched and broadened, became also apparent from other feedback from the students. When they reflected on the *Climate Garden 2085*

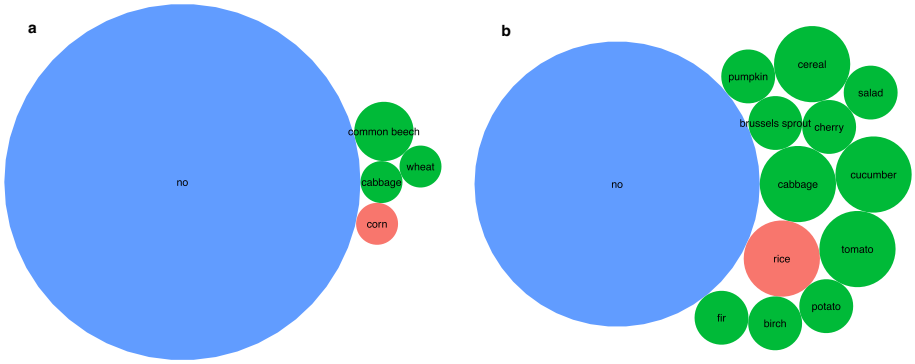

Fig. 5 Responses pre-Climate Garden to "Can you name a plant which will be a climate loser?" Left, high school, right, vocational college. Green indicates correct answers, red incorrect and the surface of the dot is proportional to the number of answers. Respondents could name more than one plant

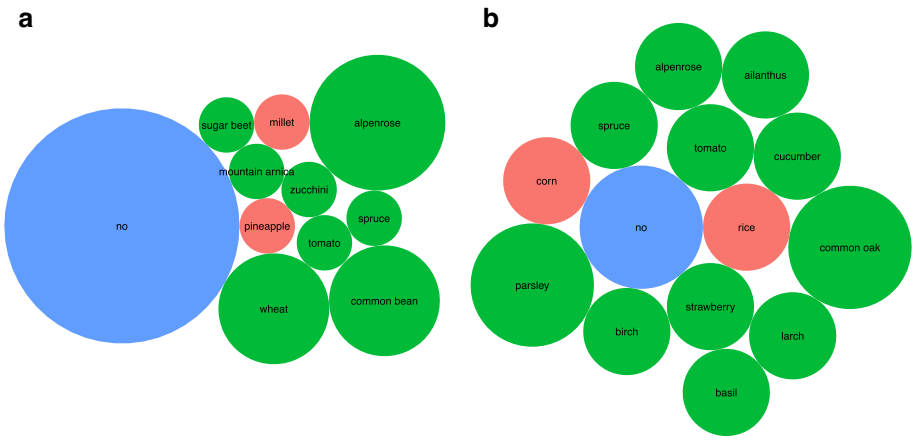

Fig. 6 Responses post-Climate Garden to the question "Can you name a plant which will be a climate loser?" Left, high school, right, vocational college. Green indicates correct answers, red incorrect and the surface of the dot is proportional to the number of answers. Respondents could name more than one plant

many participants mentioned the impact of the workshops, specifically mycorrhiza, and the plant stress experiments. They also mentioned being outside a lot and working and caring for the plants: “I think back on the great time we spent as a class in the garden, the awareness of climate change and everything we learnt”.

In the post survey 68.5% said that the *Climate Garden 2085* had “made them more aware of climate change and plants”.

4.2 Qualitative results

Unfortunately, based on the questionnaire, it was not possible to evaluate the transformative effects of the *Climate Garden 2085,* but qualitative data gave us some indication that

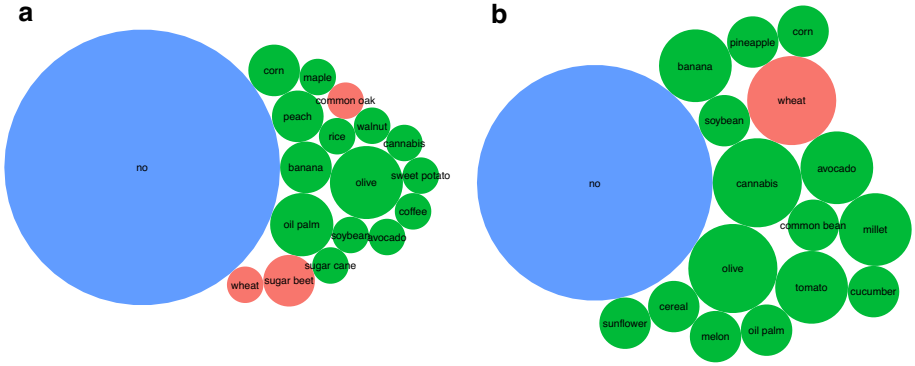

Fig. 7 Responses pre-Climate Garden to "Can you name a plant which will be a climate winner?" Left, high school, right, vocational college. Green indicates correct answers, red incorrect and the surface of the dot is proportional to the number of answers. Respondents could name more than one plant

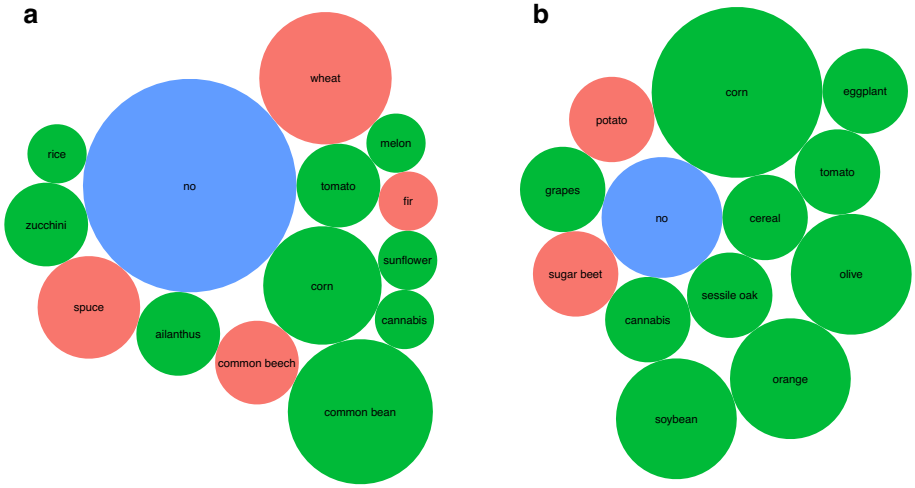

Fig. 8 Responses post-Climate Garden to "Can you name a plant which will be a climate winner?" Left, high school, right, vocational college. Green indicates correct answers, red incorrect and the surface of the dot is proportional to the number of answers. Respondents could name more than one plant

it had such an effect. Post garden there was a reported increase in talking about climate change with family and friends, yet most said nothing had changed in their school because of the project. But where there was a change, it was the establishment of a climate action group or that the school policy on school trips included no more flying. The pupils showed both before and after a social and political awareness of the measures needed to achieve climate goals.

Feedback from the involved teachers from informal discussions and from video interviews, suggested that at least in biology and geography they were able to anchor the themes in their curriculum. They perceived it as an advantage to have the *Climate Garden* as a class project for four to six months as this afforded the pupils time to carry out their own

Fig. 9 At the end of the growing season pupils divided their plants into climate winners ("Gewinner") and climate losers at the Climate Garden 2085 at the high school in Schiers in 2021 (Kantonsschule Schiers)

experiments and to observe a full growing season. It also kept the theme of climate change high on the agenda but in a very natural way. Several schools have chosen to keep the greenhouses for a further year or more. What they named as crucial for the success of the project were prosaic factors such as institutional buy in. Feedback from the workshops we carried out indicated that the experience of being able to be effective and of influencing one's surroundings, is experienced as extremely positive.

5 Discussion and lessons learnt

The *Climate Garden 2085* demonstrates a novel action-oriented approach. Schools were able to cultivate plants which were important to them (Fig. 9), design their own experiments and participate in hands on workshops. The garden is an experimental space in the category of that described by (Fraude et al., 2021) yet it allowed for a longer timeframe of engagement. The length of time that the garden affords, combined with the embodied experience and time and place for transformative reflection and communication, has proven its potential for transformative learning. One aspect of transformative learning is increasing participants ability to engage with transformative processes. As proposed by (Welzer, 2019) the hope is that from the transformative experiences of individuals, social processes emerge. Teachers' statements indicate that creating a *Climate Garden* in a school, catalyzes discussions and sets the school agenda for the duration of the installation. The *Climate Garden 2085* offers a way of framing the terms within which verbal or theoretical debate can take place. As a 'speculative infrastructure' it provides a model to act on different scales and functions as a 'truth-spot' (Gieryn, 2006) enabling participants to consider different versions of the future and crucially, their place in it. For example, the theme of

'climate winners and losers' among cultivated plants was new to pupils and provided room for imagination not previously available to them.

There were some behavioral changes in that the pupils consumed differently, they became more oriented toward local produce, and buying from better sources. However, even before the project there was a very high level of awareness and demonstration of energy saving behaviors. We saw a positive improvement in knowledge acquisition, in terms of being able to correctly name plant climate winners and losers and pupils became more aware of plant stress reactions and knew that mycorrhiza would also be affected by climate. The garden as artwork was also accompanied by plant science workshops, and furthermore, the *Climate Garden* was imbedded in the school program, so it is difficult to untangle what and how was taught in conjunction, or indeed which method was most effective. Again, from the statements of the teachers we would suggest that it was the combination of methods which proved effective in engaging the pupils. A key insight seems to be that the in-depth and long-term focus on a specific aspect of climate change, its effects on plants, gave the students a much broader and more enriched understanding, for instance helping them to think about the interplay of climate change adaptation, climate change winners and losers, and changing eating behavior. Such an experiential and concrete engagement with a complex issue based on a combination of specialized knowledge (such as on plant physiology and plant-mycorrhiza interactions) and lateral thinking turned out to be an effective strategy for transformative learning that helps students to move beyond black-and-white and pessimistic thinking and to envision actionable and positive futures.

In focusing on individual responses and individual actions to improve consumer behavior and environmental sustainability, we reflected that we risk framing action on climate change in terms of individual responsibility rather than the necessary system change (Svensson & Wahlström, 2023). There was indeed some indication that focusing on specific aspects of climate change, such as in this case plants and sustainable food, can risk competition for attention with other aspects. While students at the end of the learning experience reported more commitment toward sustainable eating, the importance given to mobility (flying) and social aspects decreased (Fig. 3).

Certainly, any pedagogical installation reduces the complexity of a subject. In our case, changes of the global climate system were simulated in local greenhouse, and thus extreme weather events such as flooding and extreme dry periods were not part of the garden itself. Equally, we focused on gardening as one specific individual and social activity. This left it open to criticism of being overly simplistic. As we all know climate change is not primarily about gardening it is about system change. Climate change is not simply about temperature increase and longer dry periods, it is about more extreme weather events and irreversible trigger points. It is possible that the greenhouse as enclosed infrastructure might give the wrong messages of controllability and containment. For these reasons, as an integral aspect of the project, we discussed with the school classes the way in which *Climate Garden 2085* might misrepresent climate change, yet function as a *boundary object*. A boundary object is an artifact that has a partly overlapping meaning in more than one discipline or stakeholder group and can therefore enable shared learning and conversations (Leigh-Star, 2010).

We wanted to test the hypothesis that an art-science experiment can engage on an affective learning level, that is, of attitude and emotions rather than cognitive understanding. In order to test this more effectively we would suggest doing individual interviews with pupils or using a questionnaire tool which enables more differentiated attitude assessment and recording of emotions. There are new tools available such as MUSE (https://www.epfl.ch/labs/emplus/projects/muse/) which uses playful

interactions with visitors to evaluate emotional engagement. Future research would involve adaptation of such a tool for our purposes.

The *Climate Garden 2085* has proved a popular tool for schools to engage their pupils with climate change and sustainability and a useful platform for pupils' own experiments and shared understanding of climate change. It remains a challenge to achieve cross disciplinary collaborations within schools. The driving force is usually a biology or geography teacher, and they find it difficult to engage other subject teachers. We will work with the project leaders in 2024 to specifically facilitate participation across the school as the project will continue with four new schools, in addition to the longer-term gardens. Additionally, we wish to encourage a network of *Climate Garden* schools so that they can better work together and share results and experiences.

6 Conclusion

Climate change education as part of Education for Sustainable Development is a challenging school subject, especially when the aim is to empower pupils to take action. We have in this article, presented an art-science project that has so far been implemented by 20 different schools to engage their pupils with climate change and sustainability. Our experience demonstrates how an artistic garden installation that creates an environment through which students can engage in an embodied experience, with concrete impacts of climate change on plants, can facilitate such transformative learning. A strength of the *Climate Garden* experiment is that it is relatively cheap and affordable for many schools and also flexible enough so that each school can link it to its specific teaching content coming from diverse thematic subjects.

Fostering climate change action requires a pedagogy approach that enables social learning and builds on elements such narratives and embodied experiences which are essential to bridge between knowledge and action. Such approaches must be better harnessed and expanded at all levels of teaching from primary school to vocational training and universities. Especially in vocational training, more interactive formats are needed that can help to link climate change concerns of young people to their future professional work. In our particular case, the *Climate Garden* approach is particularly well-suited to address professions which directly involve plants, such as landscape architecture, gardening, horticulture, agriculture and forestry, but different artistic interventions based on the same underlying teaching philosophy could be developed to target other professions. In particular, there is a need to link climate change with social issues and thus reach out to social, cultural and medical professions. We hope that our project can demonstrate how the arts are an important tool to create spaces for the imaginary and hope in a time of climate and environmental crises.

Appendix I List of survey questions

Before the climate garden.

Gender.
Age.
School.
The pandemic has been on our minds non-stop for the past year. Has climate change been an issue for you, too?
Where do you find information about climate change?
Have you heard any news about climate change from politicians/scientists or people you follow on social media (Instagram, TikTok, Facebook, Snapchat)?
Do you talk about climate change with your family or friends?
Due to global warming, it will be possible to grow new crops in Switzerland. Do you know such plants (climate winners)?
Do you know plants that can no longer be grown (climate losers)?
Do you contribute to climate protection at home? (Use the stairs instead of the elevator, don't let the water run when brushing your teeth, eat less meat, etc.).
Do you have a reusable drinking or eating cup / Tupperware / beeswax cloth?
Do you have a plant?
Do you use your plastic bottle / plastic bag multiple times?
Are local and seasonal foods important to you? Do you eat little meat? Do you eat local foods?
If yes, which foods?
Do you recycle?
Do you use CO2-heavy means of transport (plane, car)? Do you buy a lot of clothes / electronic devices?
Who are your role models? And why?
Do you know any organizations / companies / labels or start-ups that are dedicated to climate protection and sustainable nutrition?
What would be the most important action for you to reduce climate change?
If you were a federal councilor, what laws would you introduce to stop climate change?
If you were a Federal Councilor, what would you give the researchers at the university to do?
What professions will be important in the future in a society that does something about climate change?
Are you looking forward to the climate garden?
After the climate garden.
Gender Age School.
The pandemic has been on our minds non-stop for the past year. Has climate change also been an issue for you?
Where can you find information about climate change?
Have you heard any news about climate change from politicians/scientists or people you follow on social media (Instagram, TikTok, Facebook, Snapchat)?
Has the climate garden made you more aware of climate change and plants?
Has anything changed in your school because of the climate garden?
Have you talked more about climate change with your family or friends?

Due to global warming, it will be possible to grow new crops in Switzerland. Do you know which plants (climate winners)?
Do you know plants that can no longer be grown (climate losers)?
Have you contributed to climate protection at home? (using the stairs instead of elevator, not letting water run while brushing teeth, eating less meat, etc.).
Have you bought a reusable cup/tupperware/beeswax cloth?
Did you get yourself a plant?
Do you use your plastic bottle/plastic bag multiple times?
Are local and seasonal foods important to you?
Have you been eating less meat?
Have you been eating more local foods?
If so, what foods have you added to your diet?
Have you recycled more?
Did you use less CO_2-heavy transportation (airplane, car)?
Did you buy less clothes/electronic devices?
Who are your role models? And why?
Do you know any organizations / companies / labels or start-ups that are dedicated to climate protection and sustainable nutrition?
What would be the most important action for you to reduce climate change? If you were a federal councilor in a country, what laws would you introduce to stop climate change?
If you were a federal councilor, what would you give the researchers at the university to do?
What professions will be important in the future in a society that does something about climate change?
What do you think of when you remember the climate garden?

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Data availability The data in the form of survey responses are available at https://doi.org/10.3929/ethz-b-000597129. The data were evaluated according to the description in the manuscript. The plots were created using RStudio and the ggplot2 package.

Declarations

Conflict of interest The authors declare no competing interests.

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