Integrated Science 4

Clara Vasconcelos
Cristina S. C. Calheiros *Editors*

Enhancing Environmental Education Through Nature-Based Solutions

Springer

Editors
Clara Vasconcelos
Faculty of Science, CIMAR
University of Porto
Porto, Portugal

Cristina S. C. Calheiros
CIMAR
University of Porto
Matosinhos, Portugal

ISSN 2662-9461 ISSN 2662-947X (electronic)
Integrated Science
ISBN 978-3-030-91842-2 ISBN 978-3-030-91843-9 (eBook)
https://doi.org/10.1007/978-3-030-91843-9

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Chapter 19
How Nature-Based Solutions Can Contribute to Enhance Circularity in Cities

Rocío Pineda-Martos, Maria Beatrice Andreucci, Nataša Atanasova, Gösta F. M. Baganz, Cristina S. C. Calheiros, Joana A. C. Castellar, Maja B. Đolić, Darja Istenič, Antonia María Lorenzo López, Ana Rita L. Ribeiro, and Guenter Langergraber

Abstract Environmental education in different disciplines puts an accent on acquiring specialised knowledge and, while this remains essential, fostering knowledge alone, without links to real life, personal experiences, competencies, and values, is insufficient. Nature-based solutions (NBS) have the potential to be used as an educational framework that requires critical system thinking, a crucial component of truly democratic active citizenship, and raises awareness about global environmental, social, and economic issues. On the basis of NBS-related environmental education materials, we present in this chapter selected case studies that describe education for three main stakeholder groups. Concerning pupils and students, these are examples for schools and higher education, as well as pilot installations from

R. Pineda-Martos
Urban Greening and Biosystems Engineering Research Group (NatUrIB), Departamento de Ingeniería Aeroespacial Y Mecánica de Fluidos - Área de Ingeniería Agroforestal, Escuela Técnica Superior de Ingeniería Agronómica (ETSIA), Universidad de Sevilla, Ctra. de Utrera km. 1, 41013 Seville, Spain
e-mail: rpineda@us.es

M. B. Andreucci
Department of Planning, Design, Technology of Architecture, Faculty of Architecture, Sapienza University of Rome, Rome, Italy
e-mail: mbeatrice.andreucci@uniroma1.it

N. Atanasova · D. Istenič
Faculty of Civil and Geodetic Engineering, University of Ljubljana, Jamova 2, 1000 Ljubljana, Slovenia
e-mail: natasa.atanasova@fgg.uni-lj.si

D. Istenič
e-mail: darja.istenic@zf.uni-lj.si

G. F. M. Baganz
Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Müggelseedamm 301, 12587 Berlin, Germany
e-mail: g.baganz@igb-berlin.de

Faculty of Architecture, RWTH Aachen University, Schinkelstr. 1, 52062 Aachen, Germany

C. Vasconcelos and C. S. C. Calheiros (eds.), *Enhancing Environmental Education Through Nature-Based Solutions*, Integrated Science 4,
https://doi.org/10.1007/978-3-030-91843-9_19

Italy, Spain, Slovenia, Portugal, Turkey, and Germany. Different forms of facilities or organisations are included to demonstrate the possibilities of NBS-related education for practitioners. The offers for the general public comprise a mobile exhibition/demonstration unit, a social project and an animation video. Additionally, existing online platforms for knowledge sharing are summarised. The NBS concept has potential to assist the transition from current conventional education paradigms towards to a more critical systemic thinking to foster environmental citizenship as a base for environmental, social-economic, political, economic, and cultural changes on local, national, and global scales.

C. S. C. Calheiros
Interdisciplinary Centre of Marine and Environmental Research (CIIMAR/CIMAR), University of Porto, Novo Edifício Do Terminal de Cruzeiros Do Porto de Leixões, Avenida General Norton de Matos, 4450-208 Matosinhos, S/N, Portugal
e-mail: cristina@calheiros.org

J. A. C. Castellar
Catalan Institute for Water Research (ICRA), Carrer Emili Grahit 101, 17003 Girona, Spain
e-mail: jcastellar@icra.cat

University of Girona, Plaça de Sant Domènec 3, 17004 Girona, Spain

M. B. Đolić
Faculty of Technology and Metallurgy, Department of Environmental Engineering, University of Belgrade, Karnegijeva 4, 11000 Belgrade, Serbia

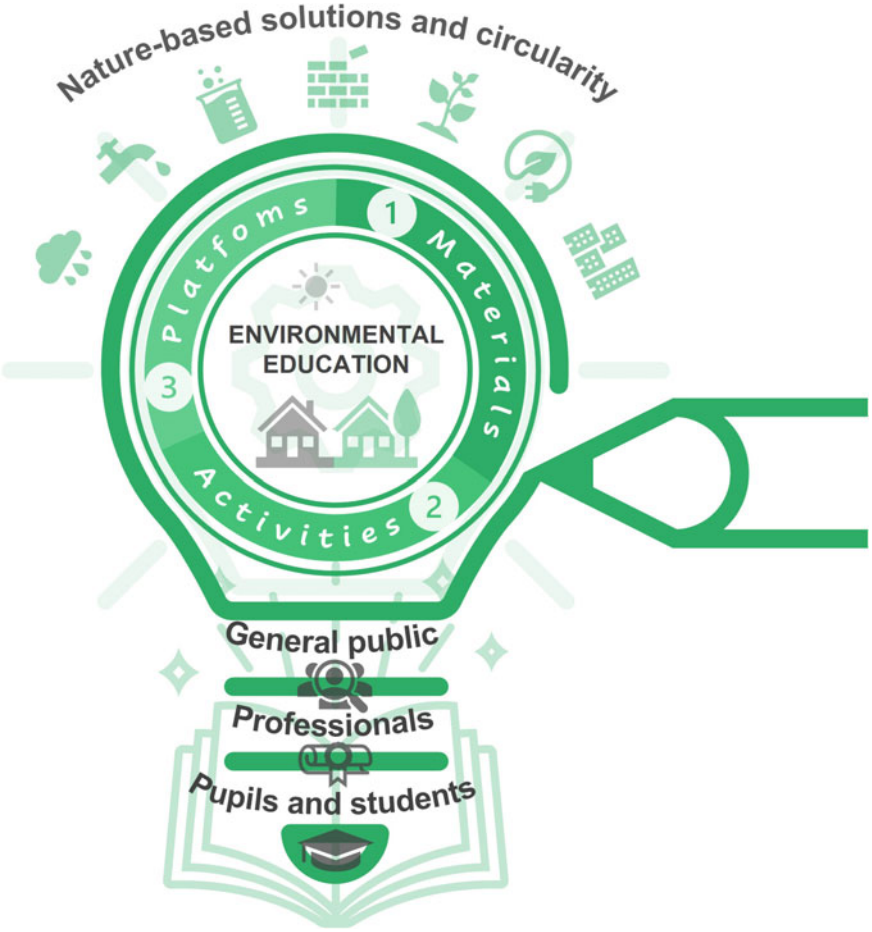
D. Istenič
Faculty of Health Sciences, University of Ljubljana, Zdravstvena pot 5, 1000 Ljubljana, Slovenia

A. M. L. López
BIOAZUL S.L, Avenida Manuel Agustín Heredia n 18, 1, 4, 29001 Málaga, Spain
e-mail: alorenzo@bioazul.com

A. R. L. Ribeiro
Laboratory of Separation and Reaction Engineering, Laboratory of Catalysis and Materials (LSRE-LCM), Faculdade de Engenharia, Universidade Do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
e-mail: ritalado@fe.up.pt

G. Langergraber (✉)
Institute of Sanitary Engineering and Water Pollution Control, Department of Water, Atmosphere and Environment, University of Natural Resources and Life Sciences, Vienna (BOKU), Muthgasse 18, 1190 Vienna, Austria
e-mail: guenter.langergraber@boku.ac.at

Graphical Abstract



Keywords Nature-based environmental education · Nature-based educational framework · Critical systemic thinking · Urban circularity challenges · Nature school · Outdoor education · Childhood education · Higher education

Introduction

While humanity recognized climate change as its major existential challenge and prepares to battle it, the need to mobilise the entire society for the task is acute. Thus, advances in environmental technologies need to be coupled with a rapid and generalised change in values and attitudes. However, there are still important hurdles

to overcome to achieve this goal. One of the most important is the current fragmentation of knowledge production and disciplinary training system. Environmental education still remains highly specialised and predominantly focused on natural sciences, with socio-political and empowerment aspects only marginally included if at all. Moreover, environmental education in different disciplines focusses on acquiring specialised knowledge and, while this remains essential, fostering knowledge alone, without links to real life, personal experiences, competencies, and values, is insufficient [1].

The COST Action CA17133 Circular City investigates how nature-based solutions (NBS) can be used to create circular economies in cities to overcome existing challenges such as resource depletion, climate change adaptation and degradation of ecosystems [2]. It is widely recognised, that NBS have potential to assist the transition from current conventional education paradigms towards to a more critical systemic thinking in order to foster environmental, social-economic, political, economic, and cultural changes, and to address transversally urban challenges such as air quality, sustainable water management, participatory planning and governance [3]).

Despite it is clear and accepted by expert community that NBS can enhance circularity in cities, the pathway to their implementation is still long and facing different barriers [2]. One of them is appropriate awareness rising and education on NBS which should be provided thoughtfully, inclusively and in well organised manner. As NBS implementation requires extremely interdisciplinary approach, the latter should be used also in education on NBS. Current lack of interdisciplinarity in majority of formal education systems limits the communications between different experts. There is a need to educate new generation of experts, and enhance the ability of professionals to be able to communicate with different expert and lay communities. Formation of interdisciplinary educational groups combining various types of knowledge or sciences like for example social, environmental and biology sciences, enables formation of new types of interdisciplinary pedagogies which combine students and pedagogues from various areas in an effort to create new, future experts capable of responding to complex challenges posed by climate change and lack of implementation of sustainable development in practice (on terrain).

In this chapter, (1) we briefly review available environmental education materials related to NBS, (2) we present selected case studies that describe educational activities for three main stakeholder groups, i.e., pupils and students, professionals such as practitioners and city administrators, and the general public (Fig. 19.1), and (3) we summarise information on existing online platforms for knowledge sharing in the field.

Environmental Education Materials Related to NBS

Institutional and non-institutional education is a crucial element in creating a positive impact on environmental behaviour. The successful implementation of the European Green Deal must also be carried out through educational system reforms to ensure

Fig. 19.1 Examples of activities related to environmental education through applications of NBS concept. **a** Productive Garden and Eco-island @ FEZ-Berlin, Germany; **b** School garden, 'Colegio Sagrada Familia', Spain; **c** NBS for informal environmental education, Greater Porto, Portugal *(Source* LIPOR, 2021); **d** Green–Blue: Sustainable Urban Drainage Project, Spain (*Source* GCMP Paisajes Resilientes https://paisajesresilientes.wordpress.com/2019/05/25/verde-azul_proyecto-de-drenaje-urbano-sostenible-dus-en-ceip-luis-bunuel-green-bluish_suds-project-in-school-luis-bunuel/); **e** NBS for building system recovery, Italy (*Source* Sapienza Master in Architecture students, 2021); **f** Green Roofs Literacy, Portugal; **g** Demo green wall for greywater treatment, Slovenia; **h** Demo green wall for improving indoor air quality, ETSIA-US, Spain; **i** LE:NOTRE Landscape Forum, EU (*Source* LE:NOTRE Student Competition 2021); **j** Courses of ANCV-Portuguese National Association of Green Roofs, Portugal; **k** Urban greening course, COIAA, Spain; **l** Demo centre of green technologies, Slovenia (*Source* Arhem Ltd. 2020); **m** MUGLI – a Mobile Exhibition Space, Austria (Source: https://gruenstattgrau.at/mugli/); **n** Animation Video, COST Action Circular City; **o** Sant Narcis 'Edible Neighbourhood', Spain

that all are equipped to meet the challenges of the future, including in those related to labour market. Therefore, 'tailored educational curricula' [4] must contain key competencies and skills needed to support a green economy. Socially and environmentally responsible behaviours may be further reinforced by impermanent education (such as through workplace retraining). Education for the future is a social challenge attached to the importance of public organizations dealing with the environment and climate change. Table 19.1 summarizes EU and international organizations dedicated to promoting environmental educational activities.

Table 19.1 European Union and international organizations dedicated to promoting environmental education activities

Organization	Description	Educational activities	Link
The United Nations Economic and Social Council (ECOSOC)	The ECOSOC supports non-profit public, volunteer organizations through consultation and access to United Nations economic and social council	Helps addressing social and economic SD challenges and improving human rights (where environmental protectionism a human right) as well as to support 'ad hoc' decision processes	https://www.un.org/ecosoc/en
The Academic Council on the UN System Institutional Member (ACUNS)	ACUNS is a global professional association of educational and research institutions, individual scholars and practitioners active in the work and study of multilateral relations, global governance and international cooperation	Promotes teaching on environmental topics, as well as dialogue and mutual understanding across and between academics, practitioners, civil society and students. Helps publishing position and opinion papers	https://acuns.org/
The European Environmental Bureau (EEB)	The EEB is Europe's largest network of environmental citizen organisations. The EEB brings together around 140 civil society organisations from more than 30 European countries. The EEB supports sustainable development, environmental justice and participatory democracy	Carries out a wide range of activities in environmental prevention and protection, among which include supporting young people in their concerns about climate change (https://eeb.org/library/pan-european-survey-climate-to-priority-for-youth/) as well as supporting NGOs and their initiatives in sustainable consumption (https://eeb.org/library/eu-strategy-for-sustainable-textiles-ngo-position/)	https://eeb.org/

(continued)

Table 19.1 (continued)

Organization	Description	Educational activities	Link
Environmental Ambassadors Sustainable Development (EASD)	EASD is one of the newest EEB members. They are a non-profit professional association working in science and research. They work through consultancy, expertise, innovation, education, the promotion of cultural values and knowledge-based advocacy	Popularizing and promoting scientific work, to enhance communication between stakeholders (representatives of local self-government, educational institutions, associations, entrepreneurs, individuals), as well as increasing public interest in sustainable development, environmental protection and education	https://eeb.org/easd-environmental-ambassadors-for-sustainable-development/
The European Citizen Science Association (ECSA)	The ECSA is a non-profit association set up to encourage the growth of the Citizen Science movement in Europe in order to enhance the participation of the general public in the scientific processes	Initiating and supporting citizen-science research and projects, as well as understanding and using its benefits in decision making	https://ecsa.citizen-science.net/
Women Engage for a Common Future (WECF)	A non-profit network dedicated to a gender justice and a healthy planet for all,WECF covers approximately 50 countries, working with 150 partner (women's and civil society) organisations in networks	The promotion of: i) holistic environmental solutions (reflecting individuals' lives); ii) gender equality and women's human rights as interconnected to climate justice; iii) sustainable energy and chemicals, reduction of toxic waste, safe water and sanitation for all	https://www.wecf.org/

(continued)

Table 19.1 (continued)

Organization	Description	Educational activities	Link
Innovation Hive	Innovation Hive is a private non-profit organization located in Greece, specialized in research and innovation	Developing educational materials, training activities and practice-driven courses that focus chiefly on systemic problems and are tailored to educators, schools across educational levels, youth and adults	https://innovationhive.eu/about-us-inno/
The Foundation for Environmental Education	Engaging and empowering individuals through education in collaboration with its members and partners worldwide	Empowering students to be leaders for sustainability and positive change through enhancing global education programs (Blue flag, Green key, Young Reporters, Learning about the Forest and Eco-schools)	https://www.fee.global/
The International Association of Universities 'Horizons'(IAU)	The IAU is the leading global association of higher education institutions and university associations. It has over 600 Member Institutions and 30 organizations	Transforming higher education for the future. It publishes a twice annual magazine outlining IAU activities	https://www.ecoschools.global/resource-material
Eco-schools	Eco-Schools has developed from a European educational programme to a global model for environmental education and sustainability	Promoting the education of students participating in the programme (workshops, eco-schools) whose actions help developing values, attitudes and behaviour towards the environment	https://www.ecoschools.global/our-history

(continued)

Table 19.1 (continued)

Organization	Description	Educational activities	Link
LE:NOTRE Institute	The LE:NOTRE Institute has been established under the auspices of ECLAS, the European Council of Landscape Architecture Schools, as an umbrella organisation for interdisciplinary collaboration between education, research and innovative practice in the landscape field. The goal of the LE:NOTRE Institute is to develop and strengthen the links between landscape education, research and innovative practice, in the public, private and not for profit sectors	What makes the LE:NOTRE Landscape Forum different from other European landscape events is the focus on dialogue, debate and discourse. It provides a unique opportunity to interact creatively with colleagues from a range of landscape disciplines in informal workshop and field visit settings. The aim is to create stimulating environment to promote the generation of both new teaching ideas and projects, for research and for collaboration between theory and practice	https://forum.ln-institute.org/lenotre-institute-2/

There is a widespread scientific opinion that mitigating pollution overall may be better carried out through increased public knowledge of environmental issues. The end result is to reinforce behaviours that promote environmental prevention and protection. Social movements in general and the environmental movement in particular are based on the premise that public education helps giving rise to supporting environmental protection and reducing the effects of climate change. Among many other definitions, the European Commission recognizes NBS as those supported by nature and ecosystems [5]. As opposed to advanced technological solutions, NBS are cost-effective, simultaneously provide environmental, social and economic benefits, as well as help building resilience to climate change. NBS public acceptance coupled by environmental education (awareness supported by knowledge) is a key for future NBS implementation. Table 19.2 provides a partial list of EU and international NBS projects along with their educational activities and initiatives.

Examples for Environmental Education Activities for Main Stakeholder Groups

Pupils and Students

FEZ-Berlin, Germany

The FEZ-Berlin is the largest Children, Youth and Family Centre in Berlin, Germany (https://fez-berlin.de/en/). It featured an eco-island (Fig. 19.1a) with a small 'tomato-fish' aquaponic system coupling fish and tomato production. The children learn about this form of sustainable food production, in which the fish water does not have to be disposed of as wastewater, but is used to irrigate and fertilise the plants. They take measurements, such as the pH value of the water, and harvest tomatoes themselves. Ms. Baganz from the research project CITYFOOD (https://www.cityfood-aquaponics.com/), which accompanies this NBS, points out that the idea of sustainable food production through aquaponics, which takes place in cities, resonates well with the children and fits with the eco-island themes of global thinking and healthy eating.

The eco-island comprises further NBS units: composting, soil improvement and conservation, urban meadows, productive garden, urban forest, and biochar/hydrochar production. In a narrative interview conducted in June 2021, Ms. Kulla from the FEZ's 'Education for Sustainable Development' team explained how they enhance environmental education: '*These are often city children who do not have much direct contact with nature. Here, the children experience nature, respect it and feel comfortable in it, they observe, learn and try out experimental ways of working. They experience biodiversity and recognise connections, even circularities. And deal with the question of how we want to live in the future. But the most important thing is that the children learn with all their senses, that they turn this into knowledge and finally integrate it into their actions*'.

Table 19.2 NBS projects and their promotional activities (education materials and initiatives)

Project title and web site	Funding (Duration of Funding)	Project's goal	Promotional activities (education materials/initiatives)	Target group	Link
Implementing nature based solutions for creating a resourceful circular city www.circular-city.eu	Horizon 2020 program, Cost Action CA17133 (2018–2021)	To create greener urban environments, enhance resource recovery and implement holistic social-economic solutions for the development of circular cities	#Mycircularcity photo contest (To promote functional and aesthetic values of NBSs in urban circularity)	Laypersons, researchers & professionals	https://circular-city.eu/?p=680
Making Cities Resilient 2030: My City is Getting Ready https://www.unisdr.org/campaign/resilientcities/advocates	UN Office for Disaster Risk Reduction (UNDRR) (2020–2030)	To establish a unique cross-stakeholder initiative that improves local (city) resilience through advocacy, sharing knowledge and experiences	Mayors and children leading the fight against climate change in the Philippines	Children	https://www.unisdr.org/campaign/resilientcities/news-events/article/17160/mayors-and-children-lead-fight-against-climate-change-in-the-philippines
New and emerging challenges and opportunities in wastewater treatment http://www.nereus-cost.eu/	Horizon 2020 program, Cost Action ES1403 (2014–2018)		A children's book: 'The Secret Handbook of the Blue circle'	Children	https://www.iwapublishing.com/news/secret-handbook-blue-circle-qa-blog-dr-despo-fatta-kassinos

(continued)

Table 19.2 (continued)

Project title and web site	Funding (Duration of Funding)	Project's goal	Promotional activities (education materials/initiatives)	Target group	Link
Nature-based Solutions Pilot teachers - Exploring Nature-Based Solutions in Your Classroom https://www.europeanschoolnetacademy.eu/courses/course-v1:Scientix+NBS+2021/about#behind	European School net Academy, European Commission (www.eun.org (January – September 2020)	15 teachers have joined the NBS project to help developing learning scenarios to integrate NBSs into the classroom	Online course on NBS (15 scenarios)	While open to all, the main target groups are primary and secondary school teachers from Europe and other regions	https://www.europeanschoolnetacademy.eu/courses/course-v1:Scientix+NBS+2021/about#topics
Grow Green http://growgreenproject.eu/	Horizon 2020 (2017–2022)	To create climate and water resilient, healthy and livable cities by investing in NBS	The Citizen engagement for NBS: Fact Sheet	The general public	http://growgreenproject.eu/wp-content/uploads/2021/03/GrowGreen-factsheet-2021-v02-1-2.pdf
UNaLab https://unalab.eu/en	Horizon 2020 (2017–2022)	To develop smarter, more inclusive, more resilient and increasingly sustainable cities through the implementation of NBS	'Urban Lab Playground: the Co-creation Game' An interactive game through which players will co-create a story line to fight against a climate-related challenges affecting our cities today	The general public, but targeting urban dwellers	https://unalab.eu/en/events/urban-living-lab-playground-co-creation-game

(continued)

Table 19.2 (continued)

Project title and web site	Funding (Duration of Funding)	Project's goal	Promotional activities (education materials/initiatives)	Target group	Link
Urban Green Up	Horizon 2020 (2017–2022)	To develop, apply and replicate 'Renaturing' Urban Plans with the aim to mitigate the effects of climate change, improve air quality and water management, as well as to increase the sustainability of cities through innovative NBS	Participation contest in Valladolid—Re—naturalise your city	Neighbourhood communities, educational centres, cultural associations	https://www.urbangreenup.eu/news--events/events/re-naturalise-your-city.kl
ProGIreg https://progireg.eu/	Horizon 2020 (2018–2023)	ProGIreg uses nature for urban regeneration with and for citizens	'proGIreg therapeutic garden' for disabled users, with green spaces for activities, relaxation and learning. It has also a 'mini-farm' for urban gardening	Disabler citizens	https://progireg.eu/news/?c=search&uid=OqiEzKpr
UrbiNat https://urbinat.eu/	Horizon 2020 (2018–2023)	URBiNAT aims to regenerate and integrate underserved city districts. The interventions focus on public spaces and the co-creation, together with citizens, of new social and NBS within and between neighbourhoods	'Focus Groups in situ' combines walking around an intervention area, observation and interviews, allowing the evaluation of positive and negative aspects to develop with the citizens an integrated vision	Citizens (including children)	https://urbinat.eu/nbs_catalogue/focus-groups-in-situ-2/

(continued)

Table 19.2 (continued)

Project title and web site	Funding (Duration of Funding)	Project's goal	Promotional activities (education materials/initiatives)	Target group	Link
Naturvation https://naturvation.eu/	Horizon 2020 (2016–2020)	The goal was to understand what NBS could achieve in cities, how innovation could be fostered, and contribute to realising the potential of NBS for responding to urban sustainability challenges	The 'Oasis for Children' aims to implement non-institutional education in 5 primary schools in Zagreb. It aims to educate pupils outdoors in school gardens, on environmental protection, sustainable development, healthy lifestyles and volunteerism	Children	https://naturvation.eu/nbs/zagreb/oasis-children
Nature4Cities https://www.nature4cities.eu/	Horizon 2020 (2016–2020)	Nature4Cities aimed to creating a comprehensive reference Platform for NBS, offering technical solutions, methods and tools to empower urban planning decision making	'Bird-Friendly garden' is one of Nature4Cities pilot sites, a school garden with diverse vegetation allowing to magnetize fauna. With a community and an educational strengthen aspect in the quality of life and in the environment, which became more peaceful, with decreased noise and air pollution	Children	https://www.nature4cities.eu/post/pilot-site-bird-friendly-garden-szeged

'Programa Aldea' (Aldea Program)—Environmental Education for the Educational Community in the Province of Andalusia, Spain

The Aldea Program: Environmental Education for the Educational Community was implemented by the Ministry of Education and Sports, and the Ministry of Agriculture, Livestock, Fisheries and Sustainable Development, in the Andalusian educational system (Southern Spain) since 1990. Updating the environmental educational offer and initiatives from a holistic perspective, the Aldea Program aims to promote innovative didactic approaches for the conservation of natural resources and the promotion of sustainable development within the Andalusian educational community.

With the intention of contributing to a more pro-environmental, just and supportive society, the Program is based on the four educational pillars proposed by UNESCO (United Nations Educational, Scientific and Cultural Organization): learning to know; learning to do; learning to live together; and, learning to be [6]. Thus, the Aldea method promotes: the development of students' key competences; the exchange of educational experiences; the work in group; the creation of professional networks; the work by projects; and other active and advanced methodologies that ultimately stimulate a change in the environmental behaviours with nature, affecting daily educational practice.

A deliverable of the Aldea Program is a Catalogue of Environmental Education Program which included the entire environmental education programs and projects—e.g., the Eco-School program [7, 8]—promoted by the Regional Government of Andalusia. The school 'Colegio Sagrada Familia, Las Francesas' (Córdoba, Andalusia) is one of the participant institutions, being involved in the program with environmental education activities on climate change, recycling and biodiversity, as the case implementation in 2021 of a school garden in its facilities (Fig. 19.1b).

NBS for Informal Environmental Education, Greater Porto, Portugal

Natural environments like green spaces have a meaningful impact on citizens' health and wellbeing [9], being inclusive NBS governance important to redresses inequalities [10]. The educational potential of NBS can be largely explored in informal education programmes for children and their families. LIPOR (Intermunicipal Waste Management Service of Greater Porto), a Municipality Association that manages, recovers, and treats the municipal waste produced in 8 municipalities of Greater Porto Area (https://www.lipor.pt) is a community-oriented company that embraces innovative projects and services, inspired by the principles of circular economy (CE). Geração + (Generation +) project was initiated in 2014 by LIPOR, motivated by the need to implement an integrated Environmental Education and Intervention strategy in the community.

The target audience of this educational project includes public/private schools (92% of 295 registered institutions, Fig. 19.1c), as well as social institutions, other associations and entities that intend to change environmental management practices.

Based on its intervention in optimizing the institution's environmental processes, Geração + works to develop practices that promote balanced waste management meeting the waste management hierarchy, by addressing several themes: reducing, re-using, recycling waste, composting, organic farming, food waste, biodiversity, water, energy, sustainable consumption, management of green spaces, and good practices of natural resources management. In each intervention area, concrete actions are carried out on the ground, thus allowing concrete economic gains for the institutions. The gains for LIPOR include the increase in recyclable waste sent for recovery and the reduction of the undifferentiated fraction of waste sent for energy recovery.

Green - Blue: Sustainable Urban Drainage Project, Spain

The project 'Green–Blue: Sustainable Urban Drainage Project' was proposed by students from the Agrarian Department of the Institute of Secondary Education No.1 (Universidad Laboral de Málaga) in the Call 'Learning with companies 2018', to the Luis Buñuel Center for Early and Primary Education (Málaga, Spain. The project, granted with 6,000 EUR, pursued the dynamization of the relations between educational centres and productive sectors.

The project is based on three pillars: (1) Sustainable Urban Drainage (SUDS); (2) participation and (3) Learning by Service—ApS. In this sense, the community service is materialized in the CEIP, where a double need was detected: (a) technical, due to the drainage problems in free areas on rainy days, difficulting transit and space use, and (b) environmental, to create a qualified space from the environmental point of view (e.g., CO_2 sink, climatic comfort, health); while working on the perception and potential of the playground as a learning space.

In the project, infiltration trench and rain garden were implemented by the CCFF students in a surface area 870 m^2, to solve a flood problem. Despite the small scope of the intervention, its design and execution has made possible to visualize the potential of Green Urban Design (GUD) in the field of integral management of water at an urban scale.

A multidisciplinary team was involved in the project development (DJP, E. Mediterraneum SL, Cuarto Creciente, Malaga City Council, the architect Celia Martínez, among others), which shows the integrative vision that the planning and management of green areas requires (Fig. 19.1d). The project was structured in three phases: Phase 1. Participation and analysis of the current situation; Phase 2. Design and construction; and Phase 3. Maintenance and community celebration.

The project started the 4th June 2018 with the workshop 'Transforming the playground through nature', focused on addressing the school playground transformation through natural elements; educating about its needs and uses; and the participatory methodologies necessary for this transformation, involving the entire educational community.

NBS for Building System Recovery, Italy

In the environmental technological design studio taught at the Faculty of Architecture of 'Sapienza' University of Rome, students are asked to develop their project focusing on NBS specialized design strategies and construction techniques to implement adaptive interventions aiming at circular cities, resilient architecture, and inclusive urban settings (Figs. 19.1e and 19.2).

The key learning objectives are: the provision of cultural and methodological references and technical and operative tools to realize NBS interventions at multiple scales [11]. The goal is to sensitise students to the need of long-run equilibrium conditions among settlements, anthropogenic activities, and natural capital, in a dynamic scenario of technological innovation and circular metabolism.

From the urban circularity challenges (UCCs) identified by Langergraber et al. [11] and Atanasova et al. [12], 'Sapienza' students concentrate on how best NBS can solve issues related to the Building System Recovery challenge [12], experimenting green walls (GW), green roofs (GR), rain gardens (biorentention cell), bioswales, treatment wetlands; and measuring integrated benefits at multiple scales, especially with respect to water cycle, water-energy nexus, and sustainable heritage restoration.

Urban NBS for circular cities is an evolving concept, where the urban ecosystem—a place of interaction between biotic and abiotic elements—represents the complex and vital system by which to pursue the rebalancing imposed by the erosion of resilience abilities due to climate change. In particular, the building's envelope and the open spaces that counteract fragmentation due to increasingly intense flows of people, materials, and information, as well as other surfaces and infrastructures.

Green Roofs Literacy, Portugal

GR are NBS that deliver a wide range of ecosystem services and perform important roles related to Water-Energy-Materials-Food-Ecosystem nexus in cities [13–15]. It is thus crucial to address the importance of GR at the level of ungraduated students, relating pivotal subjects for comprehension of the Earth System, human settlements and support the build-up of the adaptive and mitigation capacity of cities towards resources circularity [16, 17].

Three proposals are presented for educational activities addressing GR to be used by teachers or course instructors:

- GR conceptual modelling exercise: intents to support the understanding of GR as urban ecosystems through a conceptual model, enabling to communicate in a graphic language, acting as a facilitator tool to interact across different disciplines [16, 17].
- City model exercise: intents to build a maquette of a city and incorporate NBS (e.g. GR), that are of relevance to provide the students with a view of an interconnected and resourceful city, towards achieving an urban CE (Fig. 19.1f).

Fig. 19.2 Examples of design outcomes related to environmental education through application of NBS concept (students: E. Amoroso, D. Antonelli, R. Belmonte, A. Caterino, 2021)

- GR field trip: intents to deliver a clear view of how GR integrates the building and the landscape, as its interaction at different levels (social, environmental and economic).

In order to face the actual challenges for climate change adaption and mitigation and to build up more resilient societies, it is important that subjects such GR, are included in the educational programmes of the schools and at higher education level. Furthermore, there is an increasing need to have tools and educational resources available for teachers to be able to underpin hands-on examples in order to cover different fields of knowledge and entail an interdisciplinary approach.

Demo Green Wall for Greywater Treatment, Slovenia

GW can be applied to treat greywater for reuse while having simultaneous multifunctional services such as improving buildings' aesthetics, outdoor or indoor air quality, carbon dioxide (CO_2) trapping and oxygen production, temperature and acoustic comfort. Therefore, greywater separation and reuse is not only providing an alternative water source but is also a measure that can have numerous additional benefits. At the Faculty for Civil and Geodetic Engineering at the University of Ljubljana, a pilot GW (Fig. 19.1g) is serving not only for research and education purposes but also contributes to the outlook of the entrance hall and is used for promotional activities of the Faculty.

The GW was set up in 2019 and is treating synthetic greywater in horizontal flow through permeable substrate filled in four rectangular cascading beds. Additionally, a heat exchanger was set up in collaboration with the Faculty of Mechanical Engineering to study heat transfer from greywater to sanitary water. The wall is planted with indoor plants than can tolerate permanent flooding.

The GW has been used for master thesis [18] and practical work of engaged students in subjects where the concept of closing the water cycles is lectured. The subjects Wastewater treatment and Environmental technologies are available for more than a decade; however, the specific content on closing the loops is lectured since the last 3–5 years. Despite the appealing study programme and the relevance of the topic, the number of students is relatively low. The Faculty thus carries out active promotion through different media, including video and live presentations, where especial focus is given to hand on training and pilot plants such as the GW.

Pilot for Phytoremediation of Air and Water through Vertical Greening Systems in the School of Agricultural Engineering at the University of Seville, Spain

NBS demonstration sites at the School of Agricultural Engineering (ETSIA) of the University of Seville (US), Spain, consist of the application of vertical greening systems (VGS)—i.e., wall-based green facades [11]–, to improve air quality inside

buildings and water quality in ornamental ponds in the form of biofilters, and the reuse of wastewater (grey stream) and rainwater [12].

Two demonstration wall-based green facades were installed in- (Fig. 19.1h) and out-side the main entrance of the ETSIA's building, being composed of about twenty different plant species (e.g. *Ajuga reptans 'Atropurpurea'*, *Begonia rex*, *Carex flacca 'Blue Zinger'*, *Carex oshimensis 'Evergold'*, *Chlorophytum comosum*) to maximize the removal of elemental pollutants in terms of phytoremediation. The outside vertical greening—with 6 m^2 of landscape area—is integrated within an aquaponic system—i.e., pond of 20.4 m^2 and about 5,500 L of capacity with ornamental fish and aquatic plants–, which contributes to provide an additional benefit on the water purification processes, and offers recreation opportunities available at the urban University environment [19].

The potential of effective NBS to improve the environmental quality, via alleviating indoor air contamination condition, is of high interest for social innovation, both on a public and scientific level [20]. In this sense, University's students in NBS monitoring, learn and become aware about the urban pollution effects—which are directly involved with the health and well-being of the citizens–, fulfilling one of the fundamental objectives of the Academia, such as being at the service of society.

The LE:NOTRE Landscape Forum, Europe

The LE:NOTRE Landscape Forum is a discourse-oriented and interdisciplinary event of four days duration. The Forum focuses on local landscapes and the sustainability challenges they are facing. In accordance with the European Landscape Convention this includes outstanding as well as every day or degraded landscapes in urban, peri-urban, and rural environments.

The LE:NOTRE Landscape Forum is a place for interdisciplinary and multistakeholder exchange on NBS, where European students and faculties meet with city administrators, planners, architects, landscape architects, NGOs (non-governmental organisations) as well as other stakeholders. The first Landscape Forum was held in Antalya, Turkey, in 2011. The event has continued on a yearly basis since then, moving across various European locations. In 2015, the Student Competition was introduced to make the Landscape Forum more inclusive and relevant for the international community. Since then, the outcomes of the Student Competition have greatly enhanced the quality and innovation potential of the Forum as a whole.

The 2021 International Student Competition, as part of the 10th Landscape Forum of the LE:NOTRE Institute, was launched in October 2020, and was organised by the Faculty of Architecture and Design at the Academy of Fine Arts in Gdańsk, in cooperation with Gdańsk Urban Development Association. The results of the Student Competition were announced through a virtual kick-off event in April this year 2021 (https://forum.ln-institute.org/lenotre-international-student-competition-2021/), with the active participation of the students, faculties, the City of Gdańsk administrators, practitioners and various stakeholders, as well as IFLA Europe (European Association of Landscape Architects) (Figs. 19.1i and 19.3).

Fig. 19.3 Examples of winning entry in LE:NOTRE Landscape Forum student competition, related to environmental education through application of NBS concept (International Master in Landscape Architecture students from Weihenstephan-Triesdorf University of Applied Sciences and Nürtingen-Geislingen University, Germany)

Professionals

Courses of ANCV-Portuguese National Association of Green Roofs, Portugal

The NGOs or associative movements that are engaged with green infrastructure (GI) and NBS can act at different levels towards its promotion and dissemination. They often play the role to set collaboration between stakeholders and other interested parties. Besides that, they are crucial to enhance circularity in cities with NBS, providing awareness and technical knowledge through courses and short hands-on approach events [21]. As an example, is presented the case study of the Portuguese National Association of GR (ANCV, Associação Nacional de Coberturas Verdes) (https://www.greenroofs.pt). This NGO, intents to promote NBS in cities, especially GR and GW leveraging their importance and contributions to promote the creation of healthy, sustainable, biodiverse and resilient urban territories. Technical and advanced courses have been delivered in collaboration with professional orders (Ordem dos Arquitetos and Ordem do Engenheiros da região Norte), and intermunicipal communities as representative of several counties. Collaboration is also been set with schools, at the basic and secondary level, and also at the higher education level (e.g., Universities, Polytechnics), to deliver short courses or talks on the subject (Fig. 19.1j).

A strategy of dissemination and environmental education is needed to show the population, and the different groups of professionals related to the theme, the diverse and significant benefits that they offer. A key point is the literacy concerning the GR that should be escalated from the pre-school to higher educational levels, whereas technical knowledge should be assured for widespread of the technology. The role of the GR associations is very important to set a voice connecting companies, policymakers, academics, schools and citizens.

The Official College of Agricultural Engineers of Andalusia, Spain

The Official College of Agricultural Engineers of Andalusia (Colegio Oficial de Ingenieros Agrónomos de Andalucía, COIAA)—founded in 1953 –, is a Public Law Corporation which represents the Agricultural Engineering in Andalusia (Southern Spain), providing social guarantee and services for the profession. Training courses is one of the COIAA services aimed at updating or improving certified competences, knowledge and skills—appropriate to current technologies and regulations—among its professionals and practitioners (see Fig. 19.1k for details). The planning and management of training actions is entrusted to the Andalusian Foundation of Agricultural Engineers (Fundación Andaluza de Ingenieros Agrónomos). Several categories are distinguished in its wide training offer, among them: food quality and safety, and environment and renewable energies; being in the latter where the course on VGS and GR is categorized. Those interested in the urban greening course belong

to the areas of knowledge in the field of NBS (landscaping and GI); and intended to develop their career as engineers, environmental consultants and technicians. The training course program and learning activities, with the following main educational contents, are classified as:

- Urban greening: urban sustainability and benefits of urban GI.
- Built urban environment: green buildings (VGS and GR).
- Project design and implementation: technical aspects and planning.
- Irrigation and drainage systems: use of rainwater and greywater.
- Maintenance: plant protection, lighting, advanced control systems and equipment.
- Technical visits (i.e., VGS and GR implemented in the city of Seville).

Demonstration Centre on Green Technologies in Ajdovščina, Slovenia

The demonstration centre of green technologies (Fig. 19.1l) is located at the premises of the central wastewater treatment plant (WWTP) in the small town of Ajdovščina. In the framework of national research projects by the University of Ljubljana various pilot systems of NBS have been set up at first only for research purposes. Two stage constructed wetland (VF-HF), high-rate algae pond, evapotranspirative willow system and lysimeter field are demonstrating robust and sustainable treatment of municipal wastewater, production of safe and valuable side products (woody and algae biomass) and reuse of reclaimed water for vegetable fertigation in lysimeter field. The initial goal of the site that covers 1000 m^2 was to research, develop, optimize, and demonstrate NBS technologies, their products and impact on agriculture [22, 23].

After initial research activities to overcome technological barriers, the site was promoted for educational activities. First, field excursions and master thesis for students of different pre- and post-graduation environmental studies were carried out, followed by international summers schools. Later, the operator of the WWTP recognised the value of the centre to demonstrate the possibilities of NBS for decentralized wastewater treatment in small rural communities. Visits of decision makers and end users from different municipalities have been organised to present treatment wetland and banish doubts on its performance. Recently, the centre was presented to farmers which increased interest in use of reclaimed water.

Currently the centre is still closed for public, so only pre-announced visits are possible with an expert guide from the University of Ljubljana or water utility company. The plan is to turn the site from research focused centre into an open demonstration and educational centre where different target groups can learn about sustainable approaches in wastewater management and principles of closing the nutrient and water cycles. The centre will be refurbished into an attractive site for visitors with suitable infrastructure for outdoor learning courses (information boards, banks, outdoor classroom). The site would also be freely accessible and connected to local cycling route across the valley as one of the spots of interest.

General Public

MUGLI – a Mobile Exhibition Space, Austria

MUGLI (Fig. 19.1m)—the acronym stands for Mobile Urban Green Living Innovative—is the mobile exhibition space of Grünstattgrau, which is the Austrian competence centre and central coordination unit for the future of urban green environment, and innovations and ideas for green cities. The network comprises about 380 partners from the field. Since 2018, MUGLI tours through Austria (e.g., Vienna, Linz, Feldkirch, Klagenfurt) specifically for activities related to knowledge, participation management and economic and social cooperation regarding GI and NBS on buildings. MUGLI allows a first-hand experience of greening buildings and provides information and knowledge to a broad range of people. It is also a modular experimental space for existing and new technologies of the network partners. MUGLI shows different systems for the greening of roofs and both external and internal VGS. Visitors are informed by means of a guided exhibition. Through this interactive tour you will find out which different vegetation systems are possible, how different technologies work and which technology is behind them. In addition, monitoring data on the areas are used to generate measurement data for the individual systems. Through the periscope you can explore the GR with the wild bee hotel and the photovoltaic system. How nature can be combined with architecture shows MUGLI with the exhibition of beneficial devices such as nesting aids for swifts and wild bees. MUGLI aims to raise awareness and highlight the role of GI in cities to improve the quality of urban living [24].

Animation Video, COST Action Circular City

To promote its ideas, the COST Action Circular City (https://circular-city.eu/) developed an animation video (Fig. 19.1n) with English speaker voice. With the video, a positive scenario of the future using NBS in cities is shown. It is explained, how cities by using NBS can become green, beautiful, CO_2 neutral and resilient.

In the video, solutions on all levels are shown:

- Green building materials, including bio composites with plant-based aggregates;
- Green building systems, employed for the greening of buildings by incorporating vegetation in their envelope; and
- Green building sites, emphasizing the value of vegetated open spaces and water-sensitive urban design.

On the building level, the video showcases the use of plants and NBS building materials, the important role of NBS in water purification and retention as well as how buildings can be transformed as producing cell of the city. In public spaces such as parks and roads, NBS are utilised for storm water management and for prevention of urban heat islands.

The video is available at the COST Action's YouTube® channel (https://www.youtube.com/channel/UCofffnNso64Ck1limndfvTw). Besides the English speaker, the function to implement subtitles has been used to guarantee that general public can more easily understand the message of the video. Thus, the English subtitles have been translated by members of the COST Action Circular City into 34 languages. These include all national languages of the 39 COST countries, some regional languages in the COST countries (e.g., Catalan (Spain)) as well as other languages (e.g., Arabic, Chinese).

The Social Project 'Edible Sant Narcis Neighbourhood', Spain

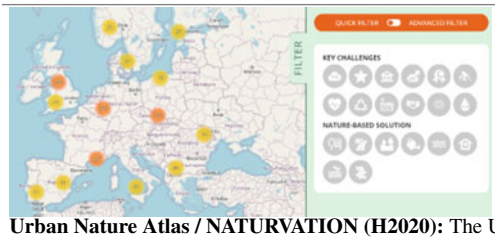
The social project 'Edible Sant Narcis Neighbourhood' started at the end of 2019. The project seeks to co-create and implement NBS, such as a community gardens, rainwater harvesting and GW, for closing the water and nutrients cycles and enhancing social engagement and awareness regarding a green and just transition (Fig. 19.1o). Inside the community garden itself, an innovative design concept for GW will be built, which puts together CE principles and NBS for treatment and reuse of greywater for urban agriculture at urban scale: the 'WETWALL' [25]. The co-creation process employs a participatory planning methodology, including from the onset municipality representatives and local stakeholders. The long-term expectations are to transform this neighbourhood into an example to be followed in terms of participative creation and implementation of circular NBS. Moreover, in a near future, the project is expected to include experimental sessions with secondary, graduate and postgraduate students of the University of Girona in order to transfer technical knowledge on design and implementations of GW and community gardens, raise awareness concerning its relevance for climate change mitigation and collect feedback regarding constraints and enablers for the uptake of such NBS.

Online Platforms for Knowledge Sharing

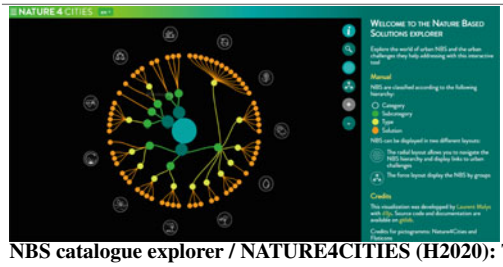
The current demand of civic society, public, private and research organisations for more sustainable and resilient cities along with limited knowledge sharing on NBS technical and practical advancements has led to the rise of online platforms to facilitate the knowledge exchange for a proper mainstreaming of NBS in cities. Therefore, in the past 5 years, a great variety of online platforms including diverse format do knowledge sharing such as catalogues, databases, interactive forums, and networking spaces and have been developed under the scope of European research and innovation programmes to support knowledge exchange on operation and maintenance of NBS. Some examples of available *online platforms for knowledge sharing* can be seen in Table 19.3.

The online platforms presented in Table 19.3 are only a small piece of what has been done in terms of online tools for knowledge sharing on NBS. Out of 70 NBS

Table 19.3 Examples of online Platforms for Knowledge Sharing



Urban Nature Atlas / NATURVATION (H2020): The Urban Nature Atlas is a collection of more than 1000 inspiring NBS from European cities and beyond. It offers the option of browsing NBS per location, type of NBS (e.g., external building green, allotments and community gardens), focus (e.g., creation of new green areas, protection for natural ecosystems), initiating organization (NGOs, private foundation) and key-challenges addressed (based on Eklipse framework [3] and Sustainable Development Goals (SDGs); e.g. cultural heritage, water management)



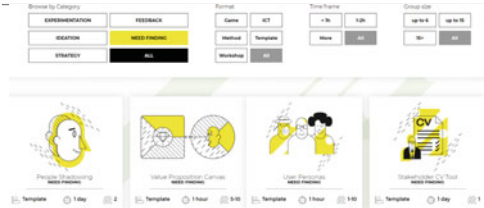
NBS catalogue explorer / NATURE4CITIES (H2020): The NBS catalogue explorer showcase more than 50 typologies of NBS classified as strategies (urban planning, protection and conservation), actions (monitoring, waste management, urban green spaces management) and physical projects (buildings, water, on the ground). The NBS are linked to potential urban challenges to be adressed (adapted from Eklipse framework [3]. Additionally, the tool offers information such as a brief description, potential co-benefits to be delivered, implementation scale and gives the possibility of downloading a comprehensive factsheet

Connecting Nature Enterprise Platform / (H2020): The Connecting Nature Enterprise platform is an online marketplace that aims to connect a wide range of NBS enterprises and organizations (e.g. individuals, enterprises, city councils, private developers, researchers, policy makers) in order to facilitate the knowledge sharing on design, management and monitoring of NBS as well as the diffusion of products/services for the planning, delivery and/or stewardship of NBS, either for economic or non-economic purposes. Therefore, the platform connects suppliers of nature with buyers of nature, nature-based enterprises with financing, innovators with those seeking inspiration, policy-makers with practitioners

(continued)

Table 19.3 (continued)

Interactive catalogue/EdiCitNet (H2020): The interactive catalogue aims to consolidate information about worldwide edible NBS (eNBS) while promoting knowledge sharing, networking, and learning among people involved or willing to get involved with these initiatives. It delivers a comphensive collection of more than 300 eNBS, in which user can get inspiration and interact with. It allows user to explore eNBS per type of products and activities offered, initial budget required, type of advertisement and funding. Aditionally, user can access the profile of eNBS to get more detailed information such as a brief description, products, activities and visual graphs of ECS performance in terms of urban challenges and ecosystem services provided. As an added value, unlike other catalogs, the interactive catalogue facilitates the creation of networks. The tool offers a set of interactive functions that make it a true social network for users. Users can leave comments and questions or follow profiles to receive updates on events and news



Tools for co-creation/UNALAB (H2020): It is a comprehensive catalogue showcasing diverse tools to support procceses for co-creation of NBS. The tools are organized according to the purposes of the co-creation process and offesrs a variety of methods, games, templates, workshops for indentification of suitable NBS in line with end-user needs and goals, generate innovative solutions through unleashing creativity and discovering valuable insights, designing action plans to achieve long-term aims, testing and validation of implemented solutions and evaluate public reaction to a solution

OPPLA: Oppla is an open platform which works as the EU Repository of NBS. It aims to promote the consolidation and creation of knowledge on NBS to better manage the environment. It is designed to support knowledge sharing across a wide range of end-users (e.g. scientistis, policy makers; public, private and voluntary sectors; as well as individuals). Therefore to offer a great variety of services and tools such as *Marketplace and case of studies*, where the latest thinking on natural capital, ecosystem services and NBS is brought together and *Ask Oppla* is crowd-sourced enquiry service designed to support knowledge exchange between users concerning topics related to NBS

tools reviewed under the scope of The ACTionNBS project, approximately 50% were informative and provide guidance through knowledge sharing mechanisms (catalogues, databases, handbooks etc.) [26]. Considering the novelty and worldwide relevance of the NBS topic, such rise number of online platforms and tools are understandable. Hence, nowadays is not a question of developing/enhancing knowledge sharing platform but to promote the integration and communication between such platforms to facilitate public access avoid segregation of end-users and thus favours long-term and suitable knowledge sharing across NBS community. Moreover, existing tools provide limited guidance concerning resources needed and their management in the sense of resources recovery. Therefore, if NBS are to be implemented as a solution to foment a sustainable resources management in cities then the tools require strictly cross-disciplinary approach and thus they must integrate data related to the performance of NBS in terms of water, food, energy, and waste management.

Conclusions

Educational activities through NBS—for which selected examples have been described in this chapter—aim to increase environmental citizenship by identifying specific target groups and reaching out to them (1) the core idea of NBS and (2) the benefits of closed loops using NBS. As different as the target groups are, as different is the approach to them and the teaching content to be imparted.

In formal higher education, existing activities cover ex-cathedra lectures, seminars and excursions, to pilot NBS for students of different graduate and post-graduate programmes. This can be upgraded by the inclusion of invited lectures from practitioners and other disciplines, round tables with businesses and farmers, workshops, hands-on exercises at demo sites, and pilot plants. The aim is to unify, consolidate and upgrade the content regarding closing the water and nutrient cycles, by enriching the existing programmes, or proposing new elective courses. The format of teaching may be improved by:

- Diversifying the existing courses with invited lectures and round tables involving lectures from other faculties and practitioners.
- Including more practical work and hands-on trainings at NBS pilot plants, and elsewhere.
- Proposing a special set of elective courses on this topic at different faculties.
- Enhancing the interdisciplinarity aspects though integration, i.e., combining a set of on-terrain exchange of knowledge, and experiences from a diverse field of sciences that deal with water management (social, environmental, spatial, biology, health, food production etc.).
- Summer schools on closed cycles management.

Additionally, education on NBS and circularity in cities needs to reach out of formal education by developing new curricula and educational activities. Depending on the desired outcome, content and methods must be adapted to target groups with very different requirements, such as children, alumni groups for lifelong learning, members of different chambers (e.g. chambers of Engineers, Agriculture and Forestry, and Architects), farmer associations and urban farmers, vocational trainings at secondary schools, employees at the municipalities, SMEs, and other stakeholders that are identified in a city, as well as the general public. It is important that students of building professions—landscape architects, architects and engineers—exchange experience and co-learn how the integration of NBS into architectural and urban design can help create more sustainable and circular urban settings, for the benefit of people and the environment.

Acknowledgements The work was carried out within the COST Action CA17133 Circular City ('Implementing nature-based solutions for creating a resourceful circular city', https://www.circular-city.eu, duration 22 Oct 2018–21 Oct 2022). COST Actions are funded within the EU Horizon Programmes. The authors are grateful for the support.

The authors acknowledge all organisations that were funding the educational activities described. Detailed information on funding of a specific activities can be found in the respective references.

Additionally, we thank Ms. Kulla from FEZ-Berlin and Ms. Baganz from IGB Berlin for their insights. The authors acknowledge Prof. Luis Pérez-Urrestarazu and Prof. Antonio Franco-Salas for provide permission to publish the ETSIA images at the University of Seville, and the images from the course at COIAA, respectively. School garden images from the 'Programa Aldea' are published by kind permission of Mr. José M. Calleja Melero and Mr. Fernando Ruiz Quero from the 'Colegio Sagrada Familia, Las Francesas'.

References

1. Hadjichambis AC, Reis P, Paraskeva-Hadjichambi D, Cincera J, Boeve-de Pauw J, Gericke N, Knippels MC (eds) (2020) Conceptualizing environmental citizenship for 21st century education. Environ Discourses Sci Educ 4, Springer Open. https://www.springer.com/de/book/9783030202484
2. Langergraber G, Pucher B, Simperler L, Kisser J, Katsou E, Buehler D, Garcia Mateo MC, Atanasova N (2020) Implementing nature-based solutions for creating a resourceful circular city. Blue-Green Syst 2(1):173–185. https://doi.org/10.2166/bgs.2020.933
3. Raymond CM, Frantzeskaki N, Kabisch N, Berry P, Breil M, Nita MR, Geneletti D, Calfapietra C (2017) A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environ Sci Policy 77:15–24. https://doi.org/10.1016/j.envsci.2017.07.008
4. Weissbrodt DG, Winkler MKH, Wells GF (2020) Responsible science, engineering and education for water resource recovery and circularity. Environ Sci Water Res Technol 6:1952–1966. https://doi.org/10.1039/D0EW00402B
5. European Commission (2021) The solution is in nature. *Future Brief* 24. Brief produced for the European Commission DG Environment. Bristol: Science Communication Unit, UWE Bristol. https://ec.europa.eu/environment/integration/research/newsalert/pdf/issue-24-2021-02-the-solution-is-in-nature.pdf. Accessed 16 Jul 2021
6. Cornu B (2005) The "four pillars" and e-education for all. In: van Weert TJ (ed) Education and the knowledge society. IFIP international federation for information processing, vol 161. Springer, Boston, MA. https://doi.org/10.1007/0-387-23120-X_20

7. González-Gaudiano EJ, Meira-Cartea PA, Gutiérrez-Bastida JM (2020) Green Schools in Mexico and Spain: Trends and Critical Perspective. In: Gough A, Lee JCK, Tsang EPK (eds) Green Schools Globally. International Explorations in Outdoor and Environmental Education. Springer, Cham. https://doi.org/10.1007/978-3-030-46820-0_15
8. Schröder L-MU, Wals AEJ, van Koppen CSA (2020) Analysing the state of student participation in two eco-schools using Engeström's second generation activity systems model. Environ Educ Res 26(8):1088–1111. https://doi.org/10.1080/13504622.2020.1779186
9. Kolokotsa D, Lilli AA, Lilli MA, Nikolaidis NP (2020) On the impact of nature-based solutions on citizens' health & well being. Energ Build 229:110527.https://doi.org/10.1016/j.enbuild.2020.110527
10. Tozer L, Hörschelmann K, Anguelovski I, Bulkeley H, Lazova Y (2020) Whose city? Whose nature? Towards inclusive nature-based solution governance. Cities 107:102892.https://doi.org/10.1016/j.cities.2020.102892
11. Langergraber G, Castellar JAC, Pucher B, Baganz GFM, Milosevic D, Andreucci MB, Kearney K, Pineda-Martos R, Atanasova N (2021) A framework for addressing circularity challenges in cities with nature-based solutions. Water, submitted
12. Atanasova N, Castellar JAC, Pineda-Martos R, Nika CE, Katsou E, Istenič D, Pucher B, Andreucci MB, Langergraber G (2021) Nature-based solutions and circularity in cities. Circ Econ Sust 1:319–332. https://doi.org/10.1007/s43615-021-00024-1
13. Calheiros CSC, Stefanakis AI (2021) Green roofs towards circular and resilient cities. Circ Econ Sust 1:395–411. https://doi.org/10.1007/s43615-021-00033-0
14. Stefanakis AI, Calheiros CSC, Nikolaou I (2021) Nature-based solutions as a tool in the new circular economic model for climate change adaptation. Circ Econ Sust 1:303–318. https://doi.org/10.1007/s43615-021-00022-3
15. Pearlmutter D, Theochari D, Nehls T, Pinho P, Piro P, Korolova A, Papaefthimiou S, Mateo MCG, Calheiros CSC, Zluwa I, Pitha U, Schosseler P, Florentin Y, Ouannou S, Gal E, Aicher A, Arnold K, Igondová E, Pucher B (2020) Enhancing the circular economy with nature-based solutions in the built urban environment: green building materials, systems and sites. Blue-Green Syst 2(1):46–72. https://doi.org/10.2166/bgs.2019.928
16. Calheiros CSC, Calafate L, Vasconcelos ML, Cardoso A, Vasconcelos C (2019a) Education for sustainability through conceptual modelling: green roofs as a way of integrating building and nature. In: Nata RV (ed) Progress in education, vol 57. Nova Science Publishers Inc., New York. ISBN 978-1-53614-799-5
17. Calheiros CSC, Lopes M, Calafate L (2019b) Educational activities to support green roofs literacy. In: Vasconcelos C, Ferreira RA, Calheiros C, Cardoso A, Mota B, Ribeiro TU (eds) XVIII Encontro Nacional de Educação em Ciências (XVIII ENEC), III International Seminar of Science Education (III ISSE). Educação em Ciências: cruzar caminhos, unir saberes, Porto Portugal, 5–7 September 2019, p 291. https://doi.org/10.24840/978-989-746-198-9. ISBN 978-989-746-198-9
18. Rutar Polanec V (2021) Green wall development for greywater treatment and heat recovery. Master thesis no.: 70/II. VOI Ljubljana, XX, University of Ljubljanan, Slovenia, 133 p.
19. González-Bermúdez AM (2017) Diseño, construcción y análisis de funcionamiento inicial de un sistema de acuaponía que combina un estanque ornamental con un jardín vertical exterior. BSc Dissertation, Universidad de Sevilla. https://idus.us.es/handle/11441/70617
20. European Commission (2020) Nature-based solutions for microclimate regulation and air quality—analysis of EU-funded Projects. European Commission, DG for Research and Innovation, Publications Office of the European Union. https://doi.org/10.2777/383904. https://op.europa.eu/en/publication-detail/-/publication/001a9517-d530-11ea-adf7-01aa75ed71a1. Accessed 16 Jul 2021
21. Pineda-Martos R, Calheiros CSC (2021) Nature-based solutions in cities—contribution of the portuguese national association of green roofs to urban circularity. Circ Econ Sust.https://doi.org/10.1007/s43615-021-00070-9

22. Griessler Bulc T, Istenič D, Prosenc F, Šunta U, Resni N, Bavcon Kralj M (2020) Reduction of environmental and health risk due to wastewater reuse in agriculture by nature-based solutions. In: Kralj-Iglič V (ed) Socratic lectures: 3rd International Mini-Symposium, Zdravstvena fakulteta, Ljubljana, 17 April 2020, p 30–39. ISBN 978-961-7112-00-9
23. Istenič D, Arias CA, Pavliha G, Griessler Bulc T (2018) Evapotranspiration and biomass production in a willow system under sub-Mediterranean climate. In: IWA (eds) Proceedings of the 16th IWA international conference on wetland systems for water pollution control, 30 September–4 October 2018. Valencia, Spain, p 587–590. ISBN 978-84-17098-53-7
24. Grünstattgrau (2021) https://gruenstattgrau.at/. Accessed 16 Jul 2021
25. Castellar JAC, Arias CA, Carvalho P, Rysulov M, Canals JM, Pérez G, Gonzalez MB, Morató JF (2018) WETWALL-an innovative design concept for the treatment of wastewater at an urban scale. Desalin Water Treat 109:205–220. https://doi.org/10.5004/dwt.2018.22143
26. Mino E, Pueyo-Ros J, Škerjanec M, Castellar JAC, Viljoen A, Istenič D, Atanasova N, Bohn K, Comas J (2021) Tools for edible cities: a review of tools for planning and assessing edible nature-based solutions. Water 13:2366. https://doi.org/10.3390/w13172366