Technical academia goes back to school: the role of universities in environmental and sustainable education for childhood

(Article begins on next page)

Technical academia goes back to school. The role of universities in Environmental and Sustainable Education for childhood.

Elena Comino[1], Laura Dominici[1*], Anna Reyneri[2], Anna Treves[1]

[1]Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, Italy; elena.comino@polito.it; laura.dominici@polito.it; anna.treves@polito.it

[2]Department of Transboundary Legal Studies, University of Groningen, NL, Oude Kijkin't Jatstraat 5/9, 9712EA; annareyneri05@gmail.com

[*]Corresponding author: laura.dominici@polito.it

Submitted 26-May-2023

Revised 19-Feb-2024

Abstract

Purpose:
This article aims to investigate the relationship between academia and society focusing on how technical universities perform Third Mission (TM) to promote knowledge outside the academic environment producing multiple benefits.

Design/methodology/approach:
This investigation is performed through the conceptual approach. The theoretical background of the Third Mission is explored through scientific literature review. It analyses a selected pool of experiences focused on Environmental and Sustainable Education (ESE). The study identifies significant aspects of two specific case studies, designed and implemented by the authors.

Findings:
Outcomes show opportunities and limitations in the application of ESE on behalf of technical academia. The study suggests solutions, precautions and systemic changes to promote ESE for childhood as TM activity in technical engineering academia. These recommendations can be useful for policymakers to set academic goals and plan the strategic management of teaching, research and TM.

Originality:
The article focuses on the role of technical engineering universities and criticalities faced by academics to foster and perform ESE. Future perspectives aim to create new opportunities to strengthen the social impact of scientific and technical research by building bridges with childhood education.

Keywords: community co-creation, environmental and sustainability education, academic third mission, experiential learning, social commitment

1. Introduction

The role of university in society has always been a debated topic (Chatterton, 2000; Bond and Paterson, 2005) since first universities were born in Europe in the early Middle Ages (Compagnucci and Spigarelli 2020). Traditionally these institutions focused on (i) the training of human capital through higher education; and (ii) the generation of new knowledge through research (Compagnucci and Spigarelli, 2020; Pinto, Cruz, and de Almeida, 2016). However, the role of universities also includes a "third mission" (TM) that fosters the academic impact on society through the education of future generations and the production of positive outcomes (Fijałkowska and Hadro, 2018). The TM seeks to generate a "social impact" outside academic environment to create economic, social and cultural benefits (Krčmářová 2011). TM goals include the knowledge and technology transfer, the promotion of academic entrepreneurship, innovation processes, the fostering of social welfare, the training of human capital and the development of science and society through various forms of communication and social engagement (Di Berardino and Corsi, 2021; Compagnucci and Spigarelli, 2020). Overall, the TM is a complex phenomenon which has evolved, and it is still changing (Giuri et al., 2019). Indeed, the academic TM lacks a common strategy to perform TM and indicators to evaluate its impacts. This gap leads universities, especially in science and technology disciplines, to define varied entrepreneurial models to perform TM based on market demands or societal challenges (Degl'Innocenti et al., 2019). The introduction of the Entrepreneurial University concept at the end of the XX century (Etzkowitz, 2004) promoted the ability of academic institutions to create new opportunities to produce economic development such as patents, research by contracts and partnerships with private companies (Boruk Klein and Mafra Pereira, 2020).

Anyway, TM goals are shaped and influenced by globalisation, financial and environmental crises, and other societal challenges (Rubens et al., 2017; Trencher et al., 2013). These dynamics require universities to assume the moral responsibility in promoting sustainable development and guiding society towards a sustainable transition (Waas, Verbruggen, and Wright, 2010). Moreover, in the framework of SDG 4 "Quality education" (Ferguson and Roofe, 2020), universities are called to take a leading role in collaboration and networking with other stakeholders to promote socio-environmental innovations (Purcell et al., 2019). Environmental education is a tool to "help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems" (UNESCO, 1978). The Environmental and Sustainability Education (ESE) represents an antidote to criticalities of the Anthropocene as it combines educational activities with ecological, economic and social dimensions (Agirreazkuenaga 2022). Universities should enhance their crucial role in research for sustainable development (Scarinci and Fornasari, 2022) by including ESE as a promising TM activity to foster ecoliteracy and to develop a critical and ecological mindset in childhood. Moreover, academics through ESE may help to clarify the meaning of some new terms such as *sustainable development* and *global environmental changes* that can be perceived as vague in primary school curricula (Sima et al., 2023).

This study aims to investigate how ESE can be considered part of TM goals by technical engineering universities which usually perform TM as knowledge and technology transfer (Rolfo and Finardi, 2014). Recently, these type of higher education institutions are increasingly focusing on social impact and public engagement, also involving children (Cognetti et al., 2022). The article aims to respond to these research questions: (i) what are challenges and opportunities faced by members of technical engineering academia that carry out ESE-related projects for middle childhood as part of TM?; (ii) which strategies can foster the implementation of ESE by technical and technological-oriented universities?

2. Methodological approach

The present study critically explores the engagement of technical engineering universities in ESE projects as TM by structuring a five-steps analysis (Figure1). The study adopts a conceptual approach, in particular the *"model"* structure, (Jaakkola, 2020) to identify main opportunities and criticalities, and provide insights for further implementations.

The first step (A) consists in defining a theoretical framework about TM through literature review that describe the interactions of academics with civic society and the importance of TM for socio-ecological transformations.

The second step (B) presents and argues characteristics of ESE projects based on nineteen projects carried out in the last 15 years by academics with children aged 6-12 years. Nineteen ESE projects have been selected worldwide from those published in scientific articles retrieved from Web of Science. Similarities and differences have been identified based on six criteria proposed as significant to describe and compare these projects. Indeed, (i) *Topic* and (ii) *Target* describe "which" kind of activities are proposed and to "whom" they are addressed, while (iii) *Team background* provides information about the disciplines to which academics belong to better understand from which experts ESE activities were carried out. Criteria (iv) *Learning spaces* and (v) *Teaching methods and tools* describe how these nineteen projects are organized and performed. At the end, (vi) *Financing* gives information about economic fundings received or allocated to support the realisation of these project. The step B aims to outline principal characteristics highlighted from ESE projects conducted by academics not only as TM but also as a part of wider research programs.

The third step (C) presents two specific case studies consisting of ESE projects proposed and designed by members of technical engineering academia in the framework of TM and carried out in collaboration with public schools and third sector. Both projects have been described and analysed using the six criteria defined in the step B.

In the fourth step (D), the nineteen projects considered in the step B and the two case studies presented in the following step C have been discussed to identify strengths, opportunities and criticalities of the scholarship engagement in ESE as TM. Pros and cons are discussed according to four criteria considered as significant for the creation of a bridge between academic and non-academic environment: (i) the *creation of synergy* between academics and other stakeholders; (ii) the diffusion of *technical vocabulary* for non-academic users; (iii) the use of *classroom as living lab*; (iv) the *integration* of ESE in national educational curricula and the overcoming of *financial hurdles*.
These four criteria are proposed by authors because they have been considered as descriptive of collaborations in the ESE framework between academics and other stakeholders. At the end, limits of the study and future perspectives to foster relationships between higher and childhood education are outlined in the conclusion section.

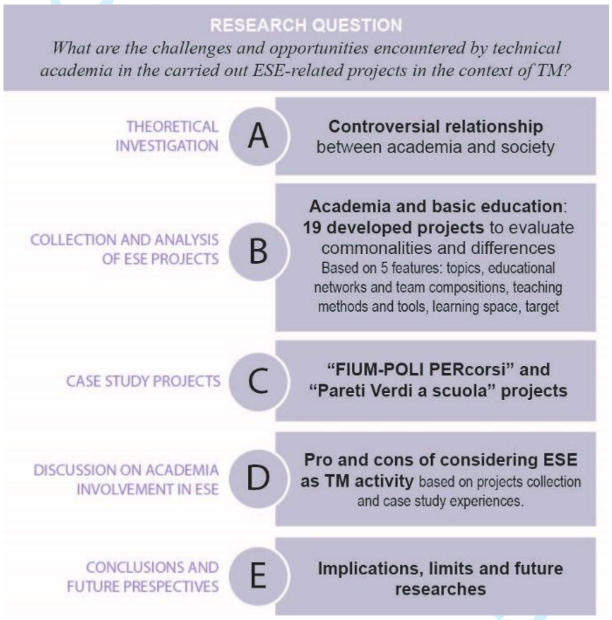

Figure 1: Scheme of methodology adopted to perform the study (Source: Authors' own creation).

3. Theoretical investigation on academia and society: a controversial relationship from ivory tower to civic engagement

The concept of academia as an "ivory tower" was challenged in 19th century by Newman who proposed the model of an independent, self-governing and social-responsible institution that produces economic and cultural impacts on the civic society (Ribolzi, 1997). Based on this dualism, the term "*Multiversity*" was later adopted to describe the multi-perspective role of universities (Kerr, 1963) and highlight the need to create bridges within a changing and challenging socio-economic context

(De Falco, 2021). During the 1980s, according to the Entrepreneurial University model, universities increased their entrepreneurial initiatives by commodifying knowledge through the creation and promotion of patents and licenses, academic spin-offs and start-ups (Gulbrandsen et al., 2007).

The relationship between academia and non-academic environment within knowledge economy can be described by using varied perspectives such as the Triple-Helix model with a predominant economic focus or the Quadruple-Helix model that includes civic society (Figure 2).

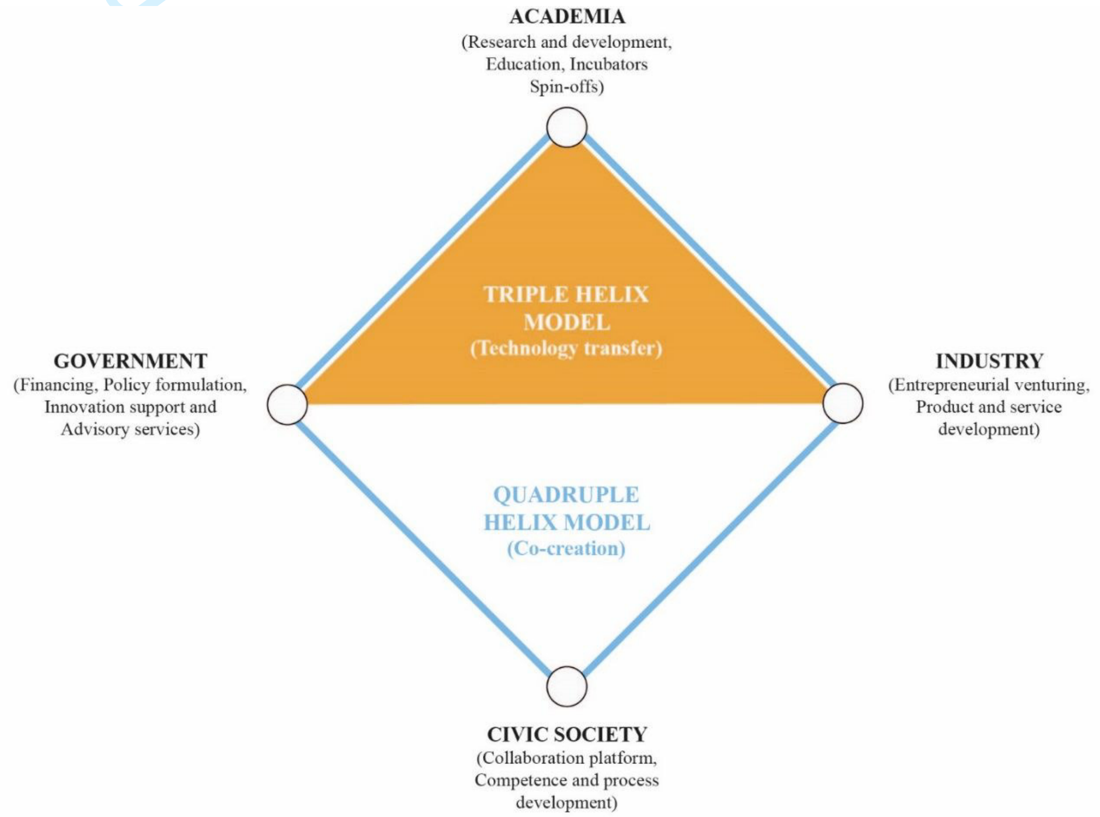

Figure 2: The Triple and Quadruple Helix Models.These models highlight the two main objectives of the third mission (i.e. Transfer technology and Co-creation) and the parties involved (i.e. Academia, Government, Industry and Civic society) with the related functions in brackets (Source: Authors' own creation).

3.1. The Golden Triangle or Triple-Helix Model

The "second academic revolution" introduced the emergence of entrepreneurial universities with the aim to transfer research findings into intellectual properties, marketable commodities and economic development (Etzkowitz, 2001). This perspective stimulated the perception that academic research is dependent on the ability to produce direct economic benefits. The Entrepreneurial University model led to the definition in 1995 of the "Triple Helix Model" or the "Golden Triangle" to describe the cross-sectorial collaboration between academia, industry, and government relations (Jongbloed, 2003; Trencher et al., 2013). In the Triple Helix Model, academia become the engine of development processes through multiple connections with enterprises and other public and private institutions (Boris and Vaissié, 2011). Nowadays, many universities perform TM following the Triple Helix Model of innovation, such as patent enhancement, technology transfer, research and consulting for third parties, or establishment of spin-off companies and technological incubators (della Volpe and Esposito, 2020). Thus, by providing socially useful tangible and intangible goods, universities emerge as important actors that perform public and social innovation and technology transfer for the whole community.

3.2. Quadruple Helix Model: towards co-creation for sustainability

The "Quadruple Helix Model" introduced in 2009 includes civic society as a key driver going beyond the mere knowledge economy and technology transfer promoted by the Triple Helix Model (Frondizi et al., 2019). The Quadruple Helix Model adopts the "co-creation for sustainability" approach as a democratic practice that fosters the collaboration with stakeholders to guide processes of social and sustainable innovation at local and regional scale (Ansell, Sørensen, and Torfing, 2022). Moreover, the natural environment was proposed as fifth helix to stress the need of a socio-ecological transition (Galvao et al., 2019).

These models propose a perspective of universities and non-academic environment that look at considerations expressed by Boyer concerning the *scholarship of engagement* (Boyer, 1996). This perspective incorporates civic engagement, public participation and democratic practices as important initiatives of scholarship to directly benefit the community and create mutual partnerships with multiple stakeholders (Barker, 2004). In some cases, these partnerships lead to the creation of "Living Labs" (LLs) as real-life experimentation environment for co-creating new sustainable practices (Paskaleva and Cooper, 2021). Indeed, LLs become spaces to experiment peer-to-peer education, problem-based and community-based learning and to promote innovation and foster socio-economic resilience (Hooli, Jauhiainen and Lahde, 2016). Academics are stimulated to co-design with stakeholders and educators ESE programs to transfer scientific knowledge to children and increase the environmental awareness of new generations (Renwick et al., 2020). Thanks to its social commitment, academia becomes a "civic university" since it "provides new opportunities for the society of which it forms part" (Goddard et al., 2016).

4. The relationship between academia and basic-level education: collection and analysis of ESE projects

This section reports results obtained by the analysis conducted on nineteen ESE projects for childhood carried out by academics from varied disciplines. The Supplementary Table 1 reports the summary of significant information retrieved from nineteen project and based on the six criteria described in the Section 2.

4.1 Topics and Target

The relationship between human and the environment is one of the most significant topic proposed by academics in ESE project addressed using varied approaches according to the background of team members (Ibarra et al., 2022; Feilen et al., 2018). Ecosystems and biodiversity conservation projects are often carried out to promote the development of biocultural memory (Ibarra et al., 2022; Feio et al., 2022), to preserve indigenous culture (Duhn and Ritchie, 2014), or to foster environmental consciousness and active engagement (O'Brian and Murray, 2007). Transdisciplinary activities proposed by Wallace (2019) in a kitchen garden introduced students to "ecological literacy", a new educational paradigm that promotes sustainable communities based on principles of ecology (Wallace, 2019). Other projects aim to create a link between different cultures, as reported by Ben-Zvi Assaraf and Orpaz (2010). Feio et al. (2022) and Khanaposhtani et al. (2018) addressed the topic of urban freshwater ecosystems and soundscape ecology, not usually dealt with in primary school education. Indeed, sampling microalgae and benthic aquatic macroinvertebrates stimulates the knowledge of aquatic ecosystems and their living organisms.

Activities proposed in these projects engaged children aged 6-14 years, and, in some cases, schoolteachers, students' families and other community members. As examples, in studies published by Cutter-Mackenzie & Edwards (2013) and Lindemann-Matthies et al. (2009) academics guided schoolteachers to adopt biodiversity conservation theories and practices in their teaching methods and approaches.

4.2 Team background and the creation of educational networks

ESE projects are often carried out by teams composed of various academic backgrounds that collaborate with external educators to foster the transdisciplinary approach into environmental education. This collaborative relationship between external educators and academics is highlighted by Dolins et al. (2010) and Duhn & Ritchie (2014) that present research activities as instruments to reinforce community through the involvement of varied stakeholders. Moreover, the introduction of an interdisciplinary staff enriches projects with various perspectives that stimulate teachers and students, and also other academic colleagues (Harvey et al. 2020; Feio et al. 2022; Ibarra et al. 2022).

4.3 Learning space and Teaching methods and tools

Learning environments is an important factor that influence learning processes, and cognitive and emotional interaction between individuals and the surrounding space (McCree et al. 2018). O'Brien & Murray (2007) and Khan et al. (2019) assert that outdoor activities stimulate students in the development of biophilic behaviour and environmental awareness (Kalvaitis and Monhardt, 2015). In addition to the positive passive influence of nature on individuals (Braun and Dierkes, 2017), these projects promote the active exploration of surrounding space to create a deeper connection with natural environment. McCree, Cutting, and Sherwin (2018) present the case of forest schools where students (5-12 years old) are involved in nature-based activities such as scavenger hunts and building wild arts shelter. The aim is to introduce students to place-based learning and experiential learning as instruments to develop skills and abilities to contribute to their communities, addressing challenges and critical issues (Morris, 2020; Moseley et al., 2020). The educational experience is developed on multiple levels and the knowledge is transferred vertically, from educators to students, and horizontally using "peer to peer" approach that involve children, educators, teachers and families. Indeed, Ghadiri Khanaposhtani et al. (2018) and Feio et al. (2022) present experiences of informal outdoor education, while Hu (2022) and Baur & Haase (2013) present new teaching approaches to environmental education, i.e. journalism and waste sorting. While, Cutter-Mackenzie and Edwards (2013) integrated a play-based approach with the tradition to stimulate the classroom during teaching. Moreover, another important support to ESE is provided using new technologies or unconventional tools such as cartoons (da Silva Caixeta et al., 2021).

5. Case study projects

This section presents two projects, "FIUM-POLI PERcorsi" and "Pareti Verdi a scuola", designed and carried out by the multidisciplinary research team of "environmental ecology" (DIATI, Polytechnic of Turin) in 2020-2021. Their main purpose was to raise environmental awareness towards topics of ecological studies: (i) the protection of freshwater ecosystems, and (ii) the importance of greenery in the urban environment. Both educational projects were developed as TM in the ESE framework. In the following paragraph "FIUM-POLI PERcorsi" and "Pareti Verdi a scuola" are described, while Supplementary Table 2 summarise overall specific characteristics.

5.1 FIUM-Poli PERcorsi project

The project "FIUM-Poli PERcorsi – Percorso Educativo Ricreativo sui corsi d'acqua" was funded by the Autorità d'Ambito Torinese3 (ATO3) in 2020-2021. It was performed during summer camps and in schools linked with the ASsociazione di Animazione Interculturale (ASAI). The project addressed the importance to protect freshwater ecosystems through recreational-educational activities. "FIUM-Poli PERcorsi" has been designed to explore themes of the river ecology and dynamics, and ecosystem management and protection. The target is represented by 130 children between 6 and 13 years old. The project involved four researchers of the "environmental ecology" team: a biologist, an ecodesigner, an environmental engineer and a hydraulic engineer. Moreover, a total of ten educators took part in the activities, supporting and facilitating researchers in conducting ESE activities. Two types of activities were proposed: (i) 2-3 hours «short» meetings in classroom and (ii) «full day» initiatives performed through outdoor education. These meetings consisted of creative workshop, playful-educational activities, interactive lectures and excursions in nature. Natural excursions were divided into stages and organised in learning-by-experience activities (i.e. observation of microorganisms) to develop new knowledge and skills.

In order to perform these activities, educational-recreational materials were prepared (didactic and educator cards, PowerPoint presentations, material for playful activities, etc.), and then distributed to children and educators (Figure 3).

Figure 3: Moments of the indoor and outdoor activities performed, and educational-recreational materials distributed to children during the activities of "FIUM-POLI PERcorsi" project (Source: Figure created by authors using their own pictures).

5.2 Pareti Verdi a scuola project

The project "Pareti Verdi a Scuola" was designed and developed in the framework of the ProGIreg, Horizon 2020 programme. The project was carried out in IC "A. Cairoli", a primary school in the Mirafiori district of Turin (Italy), and it consisted of the implementation of an indoor green wall to improve the quality of interiors. The greening system was fully financed by the ProGIreg project, instead other grants were used to develop the educational program and support researchers. “Pareti Verdi a Scuola” aimed to introduce the importance of nature and green infrastructures for the improvement of human wellbeing and the quality of the urban environment. The educational program involved 150 students between the ages of 6 and 10. The project involved three researchers of “environmental ecology” team (a biologist, an ecodesigner and an environmental engineer) who collaborated with ten schoolteachers to facilitate the activities with students. Ten meetings were organised in indoors by alternating theoretical lectures with gaming and experiential activities focused on the topic of green infrastructures generally not dealt within the primary school curriculum. Lectures were carried out interactively using slides and directly interacting with the green wall through short activities. Moreover, children and teaching staff received specific educational materials (i.e. PowerPoint presentations, didactic cards on specific topics or preparatory to lessons) used during lectures as a teaching support and to replicate these activities with other classes. A fundamental point of these meetings was the experiential aspect by directly interacting with plants and the green wall itself fostering student attitude of “caring” for nature (Figure 4).

Figure 1: Moments of the activities performed and educational materials distributed to children as support during the activities of “Pareti Verdi a scuola” project (Source: Figure created by authors using their own pictures).

6. Discussions

This section outlines pros and cons of ESE as TM activity organised in four categories presented in the Section 2. They present some important aspects and challenges that academics must consider in designing TM activities based on ESE that involve children as important part of the civic society.

6.1 Creation of synergy

The involvement of multiple stakeholders (children, teachers, families, administrative staff) is essential for the success of an ESE project. The engagement of parents and family members in educational projects enriches children experience (Hu, 2022), stimulate efficient communication with families and create a bridge between school and home education (So and Chow, 2018). The creation of wider educational networks that include institutes for primary education is a complex process for academics who must integrate needs of external stakeholders with goals and organization of higher education systems. The involvement of academics in schools requires the support of the teaching staff to create a participative and inclusive environment. In fact, the strong motivation can lead to the bottom-up initiatives of cultural changes (McCree, Cutting and Sherwin, 2018). Vice versa, if stakeholders' support and motivation are missing, the projects can be perceived as a top-down initiative unaware of community needs. Therefore, a common goal for academics and stakeholders is creating synergies to foster democratic participation, without forgetting pre-existing relationships. Indeed, the implementation of participatory approaches promotes confidence and dialogue between parties (Dolins et al., 2010) as essential actions for co-creating effective and successful ESE projects (Ibarra et al., 2022).

In the two case studies, teachers and educators have shown great support, allowing the creation of a synergistic network essential for the success of both projects. Both projects were accepted and well-integrated within regular school curricula by considering needs and interests expressed by teachers and children. Specifically, the project "Pareti Verdi a scuola" was supported by the school institution and teachers of numerous classes, increasing the social impact of the whole ProGireg project.

6.2 Development of technical vocabulary

The creation of bridges between universities and primary schools must consider differences in vocabularies adopted by academics and schoolteachers to explain same topics. The academic language is formal and technical, not always suitable to share research and innovations outside the academic environment and even less suitable for primary school children. Indeed, academics are called to adopt appropriate communication and revisit their work through the eyes of a child. An example is the adoption of the visual language using cartoons to explain and teach concepts from science and biology (da Silva Caixeta et al., 2021) or the use of play-based learning approaches (Cutter-Mackenzie and Edwards, 2013). The transition from a technical language to a more informal and familiar vocabulary brings the academics out from their comfort zone by teaching in non-familiar contexts, breaking the walls of the “ivory tower”. The collaboration with schoolteachers and educators is essential during this process because they can support and facilitate learning activities. Moreover, direct experiences facilitate the learning of technical vocabulary (Wallace, 2019) and create a strong connection with the local context, promoting an effective, relevant and understandable learning (Ben-Zvi Assaraf and Orpaz, 2010).

In the case studies, educational materials were created using comic characters and the educational activities were structured using a play-based learning approach to facilitate the understanding of new topics. This aspect brought back to school the academics involved in the two projects, giving them the opportunity for debate, the stimulus for growth and the possibility to review their approach to teaching outside higher-education contexts.

6.3 Classroom as Living Labs

Environmental education activities and programs are often based on experiential teaching that transforms schools into living labs and supports innovation processes and the increase of environmental awareness. The experience of nature links children with scientific knowledge promoting the understanding of complex topics (Ghadiri Khanaposhtani et al., 2018; Ibarra et al., 2022; Feio et al., 2022) and facilitating intergenerational dialogue on biological and cultural heritage (Ibarra et al., 2022). Living labs as immersive educational environments support children as confident learners promoting the development of social skills (McCree, Cutting, and Sherwin, 2018; Wallace, 2019). However, the transformation of classrooms as living labs can be hindered by the rigid bureaucratic process to allow the access of academics to public primary schools, as presented in the Italian context and experienced carrying out the two projects of the Section 5. On the other way, the use of classrooms as living labs is in some cases perceived as an instrumentalization of the classroom itself for research purposes involving students as participants for data collection (Ben-Zvi Assaraf and Orpaz, 2010). Although, living labs provide the opportunity to implement a win-win strategy for both academics and school stakeholders: (i) academics can perform studies by adopting action research methodology or community-driven processes; (ii) schoolteachers can integrate new and actual topics in regular primary school curricula; and (iii) young students can improve their knowledge and get in contact with members of academia who are external to the school environment.

6.4 Integration of ESE in national school curricula and financial hurdles

Economic and time constraints are extremely significant in the development of ESE programs because funds are not always available or sufficient (Harvey et al., 2020). Moreover, lack of materials, instruments and appropriate spaces are reported to be often additional limitations which may hinder the motivation of academics to perform ESE projects as TM (da Silva Caixeta et al., 2021). The integration of academia into primary education must adopt a systemic perspective introducing environmental education into the national curriculum and involving universities into this process (Salomone, 2005). Indeed, many states around the world ask for the integration of environmental education into their national curriculum adopting inclusive methods (Feio et al., 2022). Furthermore, it is important to support academics in the TM activity through its enhancement within the academic curricula and offering specific funds. Indeed, funds recruitment was a significant issue directly experienced during the implementation of both case studies here presented. For example, the "Pareti verdi a scuola" project did not received any external or specific fundings and it was carried out free of charge by the research group motivated by pure passion and interest for the project.

7. Conclusions and future perspective

This article highlights the importance of ESE as TM activity in technical engineering academia by showing benefits for both university and civic society. It also discusses some main gaps identified thank to the analysis of case studies and other experiences retrieved from scientific literature.

Even if technical academic research produces innovation to move towards sustainable development and environmental awareness, the engagement of members of technical engineering universities in basic-level education is often overlooked. Indeed, they can support efficiently sustainable innovations only if ESE projects actively involve citizens through childhood education and lifelong learning.

Limitations of this study refer to time constraints and boundaries of the research itself which could involve a larger pool of projects and academics from other disciplines to gather first hand experiences. Moreover, future research needs to focus on learning outcomes obtained by the students, teachers and stakeholders to assess the effectiveness of ESE projects.

The present study contributes to improve the existing knowledge by highlighting challenges and limits that technical academia faces in carrying out ESE as TM. These challenges concern the difficulty of expanding network outside the academic environment due to bureaucratic restrictions, not sufficient fundings to implement ESE projects, lack of acknowledgement into technical academic community for ESE as TM, and the need of shifting perspective and re-evaluation of activities focused on childhood education as academic TM.

Future steps should focus on overcoming these challenges by improving the awareness of academic community of technical universities. The creation of a wide network of aware academics in technical disciplines can lead to changes in internal policies and acknowledgments of universities with a bottom-up boost. The increasing of academic awareness can be also supported by establishing relationships with researchers from other disciplines such as humanities, as supported by the World Environmental Education Congress – WEEC Network that operates at local and international scale. The shifting of academic goals is required to promote ESE activities that reinforce relationships with external stakeholders. A win-win coordination between university policies and regulations and aware community of researchers in technical disciplines is needed to foster the scholarship of engagement. Dedicated fundings for the implementation of TM activities such as ESE for childhood and specific evaluation processes to assess their impact on civic society must be improved to enhance outcomes of research conducted in the framework of technical academia.

Acknowledgments
Authors would like to express their sincere gratitude to teachers, school staff, educators, colleagues and children (and their families) involved in project "FIUM-Poli percorsi" and "Pareti Verdi a Scuola". We appreciated their willingness and enthusiasm shown during both projects.

Funding
This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Agirreazkuenaga, Leire. 2022. "Environmental and Sustainability Education: A Critical Analysis of Evaluation Instruments through a Research–Practice Partnership." *Environmental Education Research* 28 (5). Routledge: 695–714. doi:10.1080/13504622.2022.2031898.
2. Ansell, Christopher, Eva Sørensen, and Jacob Torfing. 2022. "Co-Creation for Sustainability: The UN SDGs and the Power of Local Partnerships." *Co-Creation for Sustainability*, August. Emerald Group Publishing. doi:10.1108/9781800437982.
3. Barker, Derek. 2004. The Scholarship of Engagement: A Taxonomy of Five Emerging Practices. *Journal of Higher Education Outreach and Engagement* 9 (2): 123-137.
4. Baur, Armin, and Hans Martin Haase. 2013. "The Influence of Active Participation and Organisation in Environmental Protection Activities on the Environmental Behaviour of Pupils: Study of a Teaching Technique." *Environmental Education Research* 21 (1). Routledge: 92–105. doi:10.1080/13504622.2013.843645.
5. Ben-Zvi Assaraf, Orit, and Idit Orpaz. 2010. "The 'Life at the Poles' Study Unit: Developing Junior High School Students' Ability to Recognize the Relations between Earth Systems." *Research in Science Education* 40 (June). Springer: 525–549. doi:10.1007/S11165-009-9132-2/TABLES/5.
6. Bond, Ross, and Lindsay Paterson. 2005. "Coming down from the Ivory Tower? Academics' Civic and Economic Engagement with the Community." *Oxford Review of Education* 31 (3): 331–351. doi:10.1080/03054980500221934.

7. Boris, Pascal, and Arnaud Vaissié. 2011. "A Golden Triangle: Universities, Research and Business. A Comparative Perspective between the UK and France." *Franco-British Academic Partnerships: The Next Chapter*, January. Liverpool University Press, 193–200. doi:10.5949/UPO9781846316777.028.
8. Boruk Klein, Simone, and Federco Cesar Mafra Pereira. 2020. Entrepreneurial University: conceptions and evolution of theoretical models. *Revista Pensamento Contemporâneo em Administração* 14 (4): 20-35. doi: 10.12712/rpca.v14i4.43186.
9. Boyer, Ernst L. 1996. The Scholarship of Engagement. *Bulletin of the American Academy of Arts and Sciences* 49 (7): 18-33. https://www.jstor.org/stable/3824459.
10. Braun, Tina, and Paul Dierkes. 2017. Connecting students to nature – how intensity of nature experience and student age influence the success of outdoor education programs. *Environmental Education Research* 23(7): 937-949. doi: 10.1080/13504622.2016.1214866
11. Chatterton, Paul. 2000. "The Cultural Role of Universities in the Community: Revisiting the University - Community Debate." *Environment and Planning A* 32 (1): 165–181. doi:10.1068/a3243.
12. Cognetti, Francesca, Martin Broz, and Ida Castelnuovo. 2022. "*Public engagement and third mission. Framework and vision at the Politecnico di Milano*". Politecnico di Milano. https://www.polimi.it/fileadmin/user_upload/terza_missione/responsabilita_sociale/Public_Engagement_Polimi_eng.pdf
13. Compagnucci, Lorenzo, and Francesca Spigarelli. 2020. "The Third Mission of the University: A Systematic Literature Review on Potentials and Constraints." *Technological Forecasting & Social Change* 161 (December). North-Holland: 120284. doi:10.1016/J.TECHFORE.2020.120284.
14. Cutter-Mackenzie, Amy, and Susan Edwards. 2013. "Toward a Model for Early Childhood Environmental Education: Foregrounding, Developing, and Connecting Knowledge through Play-Based Learning." *The Journal of Environmental Education* 44 (3): 195–213. doi:10.1080/00958964.2012.751892.
15. da Silva Caixeta, Wender, Guilherme Malafaia, Lucas Benites Doretto, Ivana Felipe Rosa, Rafael Henrique Nóbrega, and Aline Sueli de Lima Rodrigues. 2021. "Cartoon as Support Material in Education for Biodiversity Conservation: The Feasibility of Using 'the Tom and Jerry Show', 'Mickey Mouse Clubhouse' and 'Masha and the Bear' Series in Elementary School." *Case Studies in Chemical and Environmental Engineering* 4 (December). Elsevier: 100123. doi:10.1016/J.CSCEE.2021.100123.
16. De Falco, Salvatore Esposito. 2021. "Funzioni e Ruoli Dell'Università Tra Storia e Innovazione." *Harvard Business Review Italia*, 98–101.
17. Degl'Innocenti, Marta, Matousek, Roman, and Nickolaos G. Tzeremes. 2019. "The interconnections of academic research and universities' "third mission": Evidence from the UK." *Research Policy* 48 (9): 103793. doi: 10.1016/j.respol.2019.05.002.
18. della Volpe, Maddalena, and Francesca Esposito. 2020. "Discursive Practices about Third Mission. A Survey from Italian Universities' Official Websites." *Https://Doi.Org/10.1080/13538322.2020.1742954* 26 (2). Routledge: 224–239. doi:10.1080/13538322.2020.1742954.
19. Di Berardino, Daniela, and Christian Corsi. 2021. "A Quality Evaluation Approach to Disclosing Third Mission Activities and Intellectual Capital in Italian Universities." *JOURNAL*

OF INTELLECTUAL CAPITAL 19 (1). Emerald Group Publishing Ltd.: 178–201. doi:10.1108/JIC-02-2017-0042.

20. Dolins, Francine L., Alison Jolly, Hantanirina Rasamimanana, Jonah Ratsimbazafy, ANNA T.C. Feistner, and Florent Ravoavy. 2010. "Conservation Education in Madagascar: Three Case Studies in the Biologically Diverse Island-Continent." *American Journal of Primatology* 72 (5): 391–406. doi:10.1002/ajp.20779.
21. Duhn, Iris, and Jenny Ritchie. 2014. "Making 'Eco-Waves': Early Childhood Care and Education Sustainability Practices in Aotearoa New Zealand." *Children, Youth and Environments* 24 (2): 123–145. doi:10.7721/chilyoutenvi.24.2.0123.
22. Etzkowitz, Henry. 2001. "The second academic revolution and the rise of entrepreneurial science." *IEEE Technology and Society Magazine* 20 (2): 18-29. doi: 10.1109/44.948843.
23. Etzkowitz, Henry. 2004. The evolution of entrepreneurial university. *International Journal of Technology and Globalisation* 1 (1): 64-77. doi: 10.1504/IJTG.2004.004551.
24. Feilen, Katie L., Rosamira R. Guillen, Johanna Vega, and Anne Savage. 2018. "Developing Successful Conservation Education Programs as a Means to Engage Local Communities in Protecting Cotton-Top Tamarins (Saguinus Oedipus) in Colombia." *Journal for Nature Conservation* 41: 44–50. doi:10.1016/j.jnc.2017.10.003.
25. Feio, Maria João, Ana Isabel Mantas, Sónia R.Q. Serra, Ana Raquel Calapez, Salomé F.P. Almeida, Manuela C. Sales, Mário Montenegro, and Francisca Moreira. 2022. "Effect of Environmental Education on the Knowledge of Aquatic Ecosystems and Reconnection with Nature in Early Childhood." *PLoS ONE* 17 (4 April). doi:10.1371/journal.pone.0266776.
26. Ferguson, Therese, and Carmel Geneva Roofe. 2020. "SDG 4 in higher education: challenges and opportunities". *International Journal of Sustainability in Higher Education* 21 (5): 959-975. doi: 10.1108/IJSHE-12-2019-0353.
27. Fijałkowska, Justyna, and Dominika Hadro. 2018. "Intellectual Capital Reporting of Universities – A Third Mission Oriented Approach to Communication with Stakeholders." *International Journal of Contemporary Management* 14 (4): 111–134. doi:10.4467/24498939ijcm.18.039.10025.
28. Frondizi, Rocco, Chiara Fantauzzi, Nathalie Colasanti, and Gloria Fiorani. 2019. "The Evaluation of Universities' Third Mission and Intellectual Capital: Theoretical Analysis and Application to Italy." *Sustainability* 11 (12): 3455. doi: 10.3390/su11123455.
29. Galvao, Anderson, Carla Mascarenhas, Carla Marques, João Ferreira, and Vanessa Ratten. 2019. "Triple helix and its evolution: a systematic literature review.". *Journal of Science and Technology Policy Management* 10 (3): 812-833. doi: 10.1108/JSTPM-10-2018-0103.
30. Ghadiri Khanaposhtani, Maryam, Chang Chia James Liu, Benjamin L. Gottesman, Daniel Shepardson, and Bryan Pijanowski. 2018. "Evidence That an Informal Environmental Summer Camp Can Contribute to the Construction of the Conceptual Understanding and Situational Interest of STEM in Middle-School Youth." *International Journal of Science Education, Part B: Communication and Public Engagement* 8 (3). Taylor & Francis: 227–249. doi:10.1080/21548455.2018.1451665.
31. Giuri, Paola, Federico Munari, Alessandra Scandura, and Laura Toschi. 2019. "The Strategic Orientation of Universities in Knowledge Transfer Activities." *Technological Forecasting and Social Change* 138 (January). North-Holland: 261–278. doi:10.1016/J.TECHFORE.2018.09.030.

32. Goddard, John, Ellen Hazelkorn, Louise Kempton, and Paul Vallance. 2016. "Introduction: Why the Civic University?" *The Civic University: The Policy and Leadership Challenges*, 3–15. doi:10.4337/9781784717728.
33. Gulbrandsen, Magnus, Stig Slipersæter, Magnus Gulbrandsen, and Stig Slipersæter. 2007. "The Third Mission and the Entrepreneurial University Model." Edward Elgar Publishing.
34. Harvey, Deborah J., Louise N. Montgomery, Hannah Harvey, Felix Hall, Alan C. Gange, and Dawn Watling. 2020. "Psychological Benefits of a Biodiversity-Focussed Outdoor Learning Program for Primary School Children." *Journal of Environmental Psychology* 67 (February). Academic Press: 101381. doi:10.1016/J.JENVP.2019.101381.
35. Helldén, Gustav, and Sofia Helldén. 2008. "Students' Early Experiences of Biodiversity and Education for a Sustainable Future." *NorDiNa* 4 (2): 123–131. doi:10.5617/nordina.286.
36. Hooli, Lauri, Jussi S. Jauhiainen, and Kristiina Lahde. 2016. "Living labs and knowledge creation in developing countries: living labs as a tool for socio-economic resilience in Tanzania." *African Journal of Science, Technology, Innovation and Development* 8 (1). doi: 10520/EJC188056.
37. Hu, Hongliang. 2022. "Rethinking Nature Journaling in the Kindergarten Program Action Research in Learning and Teaching." *Journal of Outdoor and Environmental Education* 25 (2). Springer Singapore: 159–179. doi:10.1007/s42322-022-00095-0.
38. Ibarra, Josè Tomas, Julian Caviedes, Antonia Barreau, and Natalia Pessa. 2022. "Escuchando a Los Abuelos: Transdisciplina, Aves y Gente Para Cultivar La Memoria Biocultural." *Revista Latinoamericana de Ciencias Sociales, Niñez y Juventud* 20 (3): 1–22. doi:10.11600/rlcsnj.20.2.4861.
39. Jaakkola, Elina. 2020. Designing conceptual articles: four approaches. *AMS Review* 10: 18-26. doi: 10.1007/s13162-020-00161-0.
40. Jongbloed, Ben. 2003. "Marketisation in Higher Education, Clark's Triangle and the Essential Ingredients of Markets." *Higher Education Quarterly* 57 (2). John Wiley & Sons, Ltd: 110–135. doi:10.1111/1468-2273.00238.
41. Kalvaitis, Darius, and Rebecca Monhardt. 2015. "Children Voice Biophilia; the Phenomenology of Being In Love With." *Nature Journal of Sustainability Education* 9.
42. Kerr, Clark. 1963. *The USES of the UNIVERSITY. Hardward University Press*. doi:10.1353/jhe.2003.0014.
43. Khan, Matluba, Sarah McGeown, and Simon Bell. 2019. "Can an Outdoor Learning Environment Improve Children's Academic Attainment? A Quasi-Experimental Mixed Methods Study in Bangladesh." *Environment and Behaviour* 52 (10). SAGE PublicationsSage CA: Los Angeles, CA: 1079–1104. doi:10.1177/0013916519860868.
44. Krčmářová, Jana. 2011. "The Third Mission of Higher Education Institutions: Conceptual Framework and Application in the Czech Republic." *European Journal of Higher Education* 1 (4): 315–331. doi:10.1080/21568235.2012.662835.
45. Larmore, Charles, and Paolo Costa. 2013. "A Che Serve Il Sapere?" *SOCIETÀ DEGLI INDIVIDUI (LA)*, no. 2013/46 (May). FrancoAngeli Editore: 125–136. doi:10.3280/LAS2013-046009.
46. Lindemann-Matthies, Petra, Constantinos Constantinou, Xenia Junge, Karlheinz Köhler, Jürgen Mayer, Ueli Nagel, George Raper, Diane Schüle, and Chrysanthi Kadji-Beltran. 2009. "The Integration of Biodiversity Education in the Initial Education of

Primary School Teachers: Four Comparative Case Studies from Europe." *Environmental Education Research* 15 (1). Routledge: 17–37. doi:10.1080/13504620802613496.

47. Michela Loi, Maria Chiara Di Guardo, The third mission of universities: An investigation of the espoused values, *Science and Public Policy*, Volume 42, Issue 6, December 2015, Pages 855–870, https://doi.org/10.1093/scipol/scv012
48. McCree, Mel, Roger Cutting, and Dean Sherwin. 2018. "The Hare and the Tortoise Go to Forest School: Taking the Scenic Route to Academic Attainment via Emotional Wellbeing Outdoors." *Early Child Development and Care* 188 (7): 980–996.
49. Morris, Thomas Howard. 2020. "Experiential Learning–a Systematic Review and Revision of Kolb's Model." *Interactive Learning Environments* 28 (8). Taylor & Francis: 1064–1077. doi:10.1080/10494820.2019.1570279.
50. Moseley, Christine, Haily Summerford, Melissa Paschke, Caroline Parks, and Juliana Utley. 2020. "Road to Collaboration: Experiential Learning Theory as a Framework for Environmental Education Program Development." *Applied Environmental Education and Communication* 19 (3). Routledge: 238–258. doi:10.1080/1533015X.2019.1582375.
51. O'Brien, Liz, and Richard Murray. 2007. "Forest School and Its Impacts on Young Children: Case Studies in Britain." *Urban Forestry & Urban Greening* 6 (4). Urban & Fischer: 249–265. doi:10.1016/J.UFUG.2007.03.006.
52. Paskaleva, Dr Krassimira, and Dr Ian Cooper. 2021. "Are Living Labs Effective? Exploring the Evidence." *Technovation* 106 (August). Elsevier: 102311. doi:10.1016/J.TECHNOVATION.2021.102311.
53. Pinto, Hugo, Ana Rita Cruz, and Helena de Almeida. 2016. "Academic Entrepreneurship and Knowledge Transfer Networks: Translation Process and Boundary Organizations." In *Handbook of Research on Entrepreneurial Success and Its Impact on Regional Development*, edited by L. Carvalho, 315–344. IGI Global. doi:10.4018/978-1-4666-9567-2.ch015.
54. Purcell, Wendy Maria, Heather Henriksen, and John D. Spengler. 2019. "Universities as the engine of transformational sustainability toward delivering the sustainable development goals: "Living labs" for sustainability". *International Journal of Sustainability in Higher Education* 20 (8): 1343-1357. doi: 10.1108/IJSHE-02-2019-0103.
55. Renwick, Kerry, Mark Selkrig, Catherine Manathunga, and Ron Kim Keamy. 2020. Community engagement is … : revisiting Boyer's model of scholarship. *Higher Education Research & Development* 39 (6): 1232-1246. doi: 10.1080/07294360.2020.1712680.
56. Ribolzi, Luisa. 1997. "Natura e Fini Dell'università Tra Autonomia e Controllo Statale." *Quaderni Di Sociologia*, no. 15 (November). Lexis Sas: 81–96. doi:10.4000/QDS.1546.
57. Rolfo, Secondo, and Ugo Finardi. 2014. "University Third mission in Italy: organization, faculty attitude and academic specialization." *Journal of Technology Transfer* 39: 472-486. doi: 10.1007/s10961-012-9284-5.
58. Rubens, Arthur, Francesca Spigarelli, Alessio Cavicchi, and Chiara Rinaldi. 2017. "Universities' Third Mission and the Entrepreneurial University and the Challenges They Bring to Higher Education Institutions." *Journal of Enterprinsing Communties: People and Places in the Global Economy* 11 (3): 354–372. doi:10.1108/JEC-01-2017-0006.

59. Salomone, Mario. 2005. *Educational Paths towards Sustainability.* Atti del 3° Congresso Mondiale di educazione ambientale (3rd WEEC). Torino (Italia), 2-6 ottobre 2005. ISBN 88-85313-17-5.
60. Scarinci, Alessia, and Alberto Fornasari. 2022. "How Can University Promote Eco-Literacy and Education in Environmental Sustainability? A Third-Mission Best Practice at the University of Bari." *Lecture Notes in Networks and Systems* 482 LNNS. Springer Science and Business Media Deutschland GmbH: 868–877. doi:10.1007/978-3-031-06825-6_82/COVER.
61. Sima, Mihaela, Alina-Elena Pitigoi, and Gica Pehoiu. 2023. Teachers' perception on the inclusion of environmental education in primary school curricula. Case-study: Dambovita County, Romania. *Romanian Journal of Geography* 67 (1): 23-32. doi: 10.59277/rrg.2023.1.03
62. So, Winnie Wing Mui, and Stephen Cheuk Fai Chow. 2018. "Environmental Education in Primary Schools: A Case Study with Plastic Resources and Recycling." *International Journal of Primary, Elemenary and Early Years Education* 47 (6). Routledge: 652–663. doi:10.1080/03004279.2018.1518336.
63. Trencher, Gregory, Masaru Yarime, Kes B. McCormick, Christopher N.H. Doll, and Steven B. Kraines. 2013. "Beyond the Third Mission: Exploring the Emerging University Function of Co-Creation for Sustainability." *Science and Public Policy* 41 (2). Oxford Academic: 151–179. doi:10.1093/SCIPOL/SCT044.
64. UNESCO. 1978. *Intergovernmental Conference on Environmental Education, Tbilisi, USSR, 14-26 October 1977: Final Report*.
65. United Nations Environment Programme. 1978. *Intergovernmental Conference on Environmental Education, Tbilisi, USSR, 14-26 October 1977: Final Report*.
66. Vanner, Dr. Catherine, Zoe Quenneville, Victoria Baerstoen, Vagia Tsangari, Tristan Arsenault-Carter, Tenyce Doan, Selena De Rose, et al. 2022. "The Importance of Student-Teacher Relationships." *Urban Education* 42 (4). SAGE Publications Inc.: 326–348. doi:10.1177/0042085907303406.
67. Wallace, Heather D. 2019. "Transdisciplinary Learning in a Kitchen Garden: Connecting to Nature and Constructing a Path to Ecoliteracy?" *International Research in Geographical and Environmental Education* 28 (4). Routledge: 309–323. doi:10.1080/10382046.2019.1646013.

Supplementary Table 1. Environmental educational projects collected. For each article information about country, topic, target, team background, learning space, financing, teaching methods and tools are reported (Source: table created by authors).

Article	**Country**	**Topic**	**Target**	**Team background**	**Learning space**	**Teaching methods and tools**	**Financing**
Ibarra et al., 2022	Chile	Birds and ethnoornithology - Biocultural memory	6-12 years old	Forestry, Education, Sociology	Indoor/Outdoor	Using traditional narrative Playful activities, natural history workshops and excursions	Funded by public institutions
Feio et al., 2022	Portugal	Acquatic environment - Urban stream ecosystems and their problems	6–7 years old	Marine and Environmental Science, Biology, Art and Humanities (Cultural association)	Outdoor	Use of specific tools and technologies to study microalgae (diatoms) and benthic aquatic macroinvertebrates. Field trips, laboratory class and workshop	Unfunded. Researchers involved were financed by other projects
Hu, 2022	Canada	Nature journaling	3-6 years old	Pedagogy and Environmental Education	Indoor	Nature journaling as instrument to observe nature Face-to-face and online learning context	Not specified
Baur and Haase, 2013	Germany	Waste separation	10-12 years old	Education	Indoor	Tuition and taking part in an action	Not specified
Khanaposhtani et al., 2018	USA	Soundscape ecology camp	10-12 years old	Soundlanscape ecology, Environmental education, Education, Sciences	Indoor/Outdoor	Use of specific tools and recording technologies Informal outdoor education experience	Unfunded project. Study part of a doctoral research funded by public institutions
McCree et al., 2018	England	Play in woodland - Nature connection	5–7 years old on entry to 7–10 years old on exit (three year project)	Education	Outdoor	Playful activities placed-based and nature-based	Funded project, supported by public and private institutions
Feilena et al., 2018	Colombia	Conservation of cotton-top tamarins	8-11 years old	Biology, Walt Disney animals	Indoor	Interactive and didactic teaching techniques, including games, a puppet show and activities from an activity book developed to reinforce lessons taught during the project.	Funded project, supported by public and private institutions

Wallace, 2019	Australia	Learning in a kitchen garden	9-11 years old	Education	Indoor/Outdoor	Direct experiences in kitchen garden (gardening, cooking, and science/nature inquiries)	Not specified
Ben-Zvi Assaraf and Orpaz, 2009	Israel	Life at the Poles	13-14 years old	Science and Technology Education	Indoor	The topic is presented as the "story" of the effect of human beings on the survival of living creatures (such as penguins and polar bears) at the poles. Transition from a learning unit to another through specific questions. Use of different learning environment (Article from National Geographic, Laboratory activity, outdoor learning environment, web-based activities and films)	Not specified
Harvey et al., 2020	UK	Biodiversity in school grounds	8–11 years old	Psychology and Biological Science	Outdoor	Learning materials were prepared and educational activities performed Biodiversity-focused activities: discovering/monitoring species and building new habitats/food sources (e.g. bird boxes)	Unfunded. Researchers involved were financed by other projects
Khan et al., 2019	Bangladesh	Design of school ground	8-11 years old	Public Health	Outdoor	Mathematical and Science class physically attended outside	Funded by public institutions
So and Chow, 2019	Hong Kong	Plastic resources and recycling practice	9-12 years old	Science and environmental studies, Education	Indoor	Learning materials for implementing activities focused on plastic recycling and classification, life cycle of plastics, upcycling of plastics, environmental issues of plastic waste, plastic managements in Hong Kong, and a plastic-free lifestyle with worksheets. Teaching plans, experiment guidelines, presentation files and video clips for teachers' use. Hands-on experiences of plastic recycling and sorting.	Not specified
Silva Caixeta et al., 2021	Brazil	Environmental issues	6-7 years old	Science and Biology	Indoor	Cartoons as supporting materials to teach concepts form science and biology	Funded by public institutions
Dolins et al., 2010	Madagascar	Fauna and flora of Madagascar, in particular lemurs - Biodiversity conservation project	Different segments of society among which children	Behavioural science, Biology and Environmental Science, Wildlife conservation,	Indoor/Outdoor	Participative approach (partners and target audience). Alternative communication tools to facilitate transmission of messages and alternatives (games, slogans, banners, and audio-visual tools help reach illiterate audiences). Outdoor classrooms about	Partially funded by public and private institutions

						rainforest and demonstrations of alternatives to forest destruction (e.g., improved agricultural techniques, bee keeping, and fish farming). Biodiversity topic-based classes include information about the lemurs, birds, and medicinal plants. Theme-based training and practical classes in agriculture practices and harvests. Take care activities of nursery tree for reforestation programs.	
G. Hellden and S. Hellden, 2008	Sweden	Biodiversity and organisms in the different ecosystem	10-12 years old	Science education, Education	Indoor/Outdoor	Direct experiences of four different ecosystem	Not specified
Duhn and Ritchie, 2014	New Zealand	Sharing and preserving Maori environmental culture	Children (age not specified) and teachers	Education	Indoor/Outdoor	Ethnographic and narrative methodologies	Funded by public institution
O'Brien and Murray, 2007	UK	Forest school - Environmental consciousness	Children (age not specified)	Sociology and Economy	Indoor/Outdoor	Class physically attended in Forest school	Not specified
Cutter-Mackenzie and Edwards, 2013	Australia	Environmental issue	Children (age not specified) and teachers	Education, Pedagogy	Indoor	Play-based learning (open-ended play, modelled play, purposefully framed play)	Funded by public institution
Lindemann-Matthies et al., 2009	Cyprus, UK, Switzerland, and Germany	Environmental education	Student teachers	Environmental Sciences, Biology, Education, Technology	Indoor/Outdoor	Interactive, hands on and cooperative learning	Funded by public institutions

Supplementary Table 2. Case studies projects developed by the research team (Source: table created by authors).

Project title	Country	Topic	Target	Team background	Learning space	Teaching methods and tools	Financing
FIUM-Poli PERcorsi	Italy	Protection of waterways and river ecosystems	6-13 years old	Biology, Environmental engineering, Design, Hydraulic engineering	Indoor/Outdoor	Educational-recreational material (didactic and educator cards, PowerPoint presentations, material for playful activities, etc.) Excursions, interactive lessons and playful-experiential activities	Funded by public institution
Pareti verdi a scuola	Italy	The importance of greenery in the urban environment	6-10 years old	Biology, Environmental engineering, Design	Indoor	Indoor lectures interspersed with playful and experiential activities. Experiential activities with green wall structure and plants	Unfunded. Researchers involved were financed by other projects

Elena Comino

Associate Professor of Applied Ecology at the Polytechnic of Turin (Italy). MSc in Biology, Master in Environmental Engineering and PhD in Environmental Geological Engineering. Her work is oriented in the fields of environmental sustainability. She coordinates a group of interdisciplinary team, technical specialists, young researchers and students, carrying out several research and environmental education projects.

Laura Dominici

Post-doc researcher at the Department of Environment, Land, and Infrastructure Engineering and Assistant Professor at the Polytechnic University of Turin (Italy). MSc in Ecodesign and PhD in Management, Production and Design at the Polytechnic University of Turin. Her research deals with sustainable design practices and technological greening in urban environment, with a focus on vertical greening systems. She collaborates in project of environmental education.

Anna Reyneri

Employed in a private consulting firm as a sustainability analyst. Acquired a LL.M. in Energy and Climate Law from Groningen University (NL), where she worked as a teaching and research assistant in the Department of Transboundary Legal Studies.

Anna Treves

PhD student in Urban and Regional Development at the Polytechnic of Turin (Italy) and research fellow in environmental education projects. MSc in Environmental Engineering. Her research deals with management models of interactions between humans, species and the environment. Specifically, she studies the freshwater ecosystem and the beaver, focusing on the socio-ecological dynamics related to this animal.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: