

POLITECNICO DI TORINO
Repository ISTITUZIONALE

Engaging students in Circular Design: teaching experiences with (future) architects and designers.

Original

Engaging students in Circular Design: teaching experiences with (future) architects and designers / Montacchini, E., Tedesco, S., Di Prima, N.. - (2024), pp. 979-987. (First International Conference on Sustainable Energy Education – SEED 2024 Valencia (ESP) 3 - 5 July 2024).

Availability:

This version is available at: 11583/2992958 since: 2024-10-01T09:47:35Z

Publisher:

Editorial Universitat Politècnica de València

Published

DOI:

Terms of use:

This article is made available under terms and conditions as specified in the corresponding bibliographic description in the repository

Publisher copyright

(Article begins on next page)

First International Conference on Sustainable Energy Education (SEED 2024)

Book of proceedings



SEED

sustainable energy education



UNIVERSITAT
POLITÈCNICA
DE VALÈNCIA



edUPV

Universitat Politècnica de València



First International Conference on Sustainable Energy Education (SEED 2024)

Valencia, Spain, 3-5 July 2024



edUPV

Universitat Politècnica de València

Congress UPV

Proceedings of the First International Conference on Sustainable Energy Education (SEED 2024)

The contents of this publication have been double-blind peer-reviewed by the Program Committee.

© Scientific Editors

Elena de la Poza Plaza
Amparo Blázquez-Soriano
Ruijing Wang
Annamaria Sereni

© Texts The authors

© Publisher

2024, Editorial Universitat Politècnica de València
Cno. de Vera, s/n.
46022 Valencia (SPAIN)
www.lalibreria.upv.es / Ref.: 6795_01_01_01

ISBN 978-84-1396-271-9

DOI <http://dx.doi.org/10.4995/SEED2024.2024.19007>

First International Conference on Sustainable Energy Education (SEED 2024)

This book is licensed under a [Creative Commons Attribution-NonCommercial-ShareAlike-4.0 International license](https://creativecommons.org/licenses/by-nc-sa/4.0/)
Editorial Universitat Politècnica de València <http://ocs.editorial.upv.es/index.php/SEED/SEED2024>

Organizing Committee

General chair

Elena de la Poza Plaza, Universitat Politècnica de València

Vice-chair

Amparo Blázquez-Soriano, Universitat Politècnica de València

Scientific committee

Martijn Rietbergen, University of Applied Science Utrecht

Mariola Guarinos, AVAESN

Evridiki Mantela, Bioeconomy and Environment Cluster Western Macedonia

Semih Severengiz, Bochum University of Applied Sciences

Local organization

María Natividad Guadalajara Olmeda, Universitat Politècnica de València

Pedro Fuentes Durá, Universitat Politècnica de València

Ruijing Wang, Universitat Politècnica de València

Annamaria Sereni, Politecnico di Milano

Alberto Celani, Politecnico di Milano

Program Committee

Maria Ángeles Alcaide González, Universitat de València

Catarina Afonso, Instituto Politécnico de Leiria

Joyce Aguiar, Centre for Research in Higher Education Policies

Ingrid Ahrens Massey, Northeastern State University

Safaa Al Tameemi, Munster Technological University

Rolando Angel-Alvarado, Universidad Pública de Navarra

Elisa Alen, University of Vigo

Nazim Ali, Keele University

Paula Álvarez Huerta, Mondragon Unibertsitatea

Inmaculada Aranaz, Universidad Complutense De Madrid

Núria Arenas Peiró, IES Maria Ibars, Denia

Pablo Arés Gastesi, CEU San Pablo

Sami Areva, Solar Finland Ltd

Elena Arroyo, Universidad Complutense de Madrid

Sarah Aynsley, Keele University

Mercedes Elisa Aznar Jimenez, Florida Universitària

Johan Baldeon, Pontificia Universidad Católica del Perú

Robert Barthorpe, University of Sheffield

M^a Elvira Barrios Espinosa, University of Málaga

Anita Batisti, Fordham University

Fernando Battista, Università di Roma Tre

Mi-Yong Becker, Bochum University of Applied Sciences

Werner Beyerle, Karat EDV Ltd & Co KG

Lucía Bellés Calvera, Universitat Jaume I

Dina Berzina, University of Latvia

Jorrit Bock, Royal Haskoningdhv

Sofia-Natalia Boemi, Cluster of Bioeconomy and Environment of Western Macedonia

Montserrat Boronat Navarro, Universitat Jaume I

Naomi Braithwaite, Nottingham Trent University

Alma Maria Cabanes Machancoses, CIPFP Vicente Blasco Ibáñez, València

Maria Giulia Cantiani, University of Trento

Javier Carballeira Morado, Universitat Politècnica de València

Daniela Casiraghi, Politecnico di Milano

Valeria Caviezel, University of Bergamo

Alberto Celani, Politecnico di Milano

Cristiana Cervini, University of Bologna

Guido Charosky, Universitat Politècnica De Catalunya

Augusto Cocorullo, University of Naples Federico II

Todd Cochrane, Nelson Marlborough Institute of Technology

Pauline Collins, University of Southern Queensland

Erika Corradini, University of Southampton

Jelena Davidova, Daugavpils University

Raúl De Arriba Bueno, Universitat de València

Diane Debacker, University of Kansas

Jiska De Groot, University of Cape Town

Olga Maria Diaz Godoy, Universidad de Los Llanos

Stefanos Dodouras, Cluster of Bioeconomy and Environment of Western Macedonia

Faith Dowelani, University of Pretoria

Yolanda Echegoyen Sanz, Universitat de València

Katalin Eklícsné Lepenye, University of Pécs

Estefanía Mourelle Espasadín, Universidade da Coruña

Ana Estima, University of Aveiro

Juraj Fabus, Zilinska Univerzita V Ziline

Yannis Fallas, Cluster Of Bioeconomy And Environment Of Western Macedonia

Jonathan Fanning, University of York

Miguel Ferrando Rocher, Universidad de Alicante

Paula Figas, Kempten University of Applied Sciences

Tania Fernández Navarro, Regional General Directorate of Vocational Training (GVA)

Nuno Flores, Universidade do Porto

Efrén Forcada Gallén, CIPFP Vicente Blasco Ibáñez, València

Pedro Fuentes, Universitat Politècnica de València

Diego Galego, University Aveiro

César García, Universidad Politécnica de Madrid

Moisés García Morales, Universidad de Huelva

Suzanne Gatt, University of Malta

Stefanos Gerardis University of Western Macedonia

Ramón Gero, Eiffage SA

Giorgio Giorgi, Universidad Complutense de Madrid

Tanja Glusac, Curtin University

Boudewijn Grievink, Katapult

Mariola Guarinos Ripoll, Avaesen

Maria Lucia Guerrero Farias, Universidad de Los Andes

Rabah Halabi, Oranim College

Minna Harju, Raisio Regional Education and Training Consortium

Jessica Harris, State University of New York

Aleksi Heinonen, Turku University of Applied Sciences

Kalle Hentula, Salo Solar Ltd

Katrin Herget, University of Aveiro

Fionna Heuff The Raisio Regional Education and Training Consortium

Carme Huguet, Universidad de Los Andes
Gerben Huiszoon, Scalda
Valasia Iakovoglou, Unesco and International Hellenic University (Ihu)
Nagore Ipiña, Mondragon Unibertsitatea
Marinela Istrate, University of Iasi
Magdalena Jiménez, University of Granada
Beatriz Jimenez Parra, Universidad de León
Isabel João, Instituto Superior de Engenharia de Lisboa
Kostas Karamarkos, Just Transition Institute
Natassa Kazantzidou, IDEC
Monique Kevy, University of Johannesburg
Kimmo Keinästö, RASEKO
Marlena Kilian, Cardinal Stefan Wyszyński University
Andreas Knie, Berlin Social Science Center
Theofano Kollatou, University of Western Macedonia
Safak Korkut, University of Applied Sciences and Arts Northwestern Switzerland
Miriam Korstanje, Katapult
Athina Krestou, University of Western Macedonia
Angelique Kritzinger, University of Pretoria
Aleksandra Kulpa-Puczynska, Uniwersytet Kardynała Stefana Wyszyńskiego
Emmanuel Kypraios, Maynooth University
Ignacio Laiton Poveda, Instituto Técnico Central Bogotá
Damian Lampert, Universidad Nacional de Quilmes
María Landín, Universidad Veracruzana
Yvette Lanting, University of Applied Science Utrecht
Jan Lauwerijssen, Roc Midden Nederland
Anna Logan, Dublin City University

Pauline Logue, GMIT, Atlantic Technological University
Gaia Leandri, Università Degli Studi Di Genova
Carlos Lerma Elvira, Universitat Politècnica de València
Luca Andrea Ludovico, Università degli Studi di Milano
Bence Lukacs, Technische Hochschule Nürnberg Georg Simon Ohm
José Manuel Luna Vicente, IES La Marxadella, Torrente
Inese Lusena Ezera, Liepaja Universiy
Nicolaas Luwes, Central University of Technology
Francesco Maria Mancini, Curtin University
Marco Manfra, University of Ferrara
Evriliki Mantela, Bioeconomy and Environment Cluster Western Macedonia
George Marnellos, Aristotle University of Thessaloniki
Stergios Maropoulos, University of Western Macedonia
Susana Martí Sendra, IES María Ibars, Denia
Teresa Martín García, Universidad de Salamanca
Robert Martínez Carrasco, Universitat Jaume I
Mónica Martínez Gómez, Universitat Politècnica de València
Loreto Mate Satué, Universidad de Zaragoza
Lorena Mathien, SUNY Buffalo State
Eleonora Mattarelli, La Sapienza University
Valeria Medarova, School of Management Bratislava
Noemí Merayo, Universidad de Valladolid
Paloma Merello Gimenez, Universitat de València
Carla Isabel Montagud Montalva, Universitat Politècnica de València
Gemma Montalvo, University of Alcalá
Elvira María Montañés Brunet, Universitat de València
Darlinda Moreira, Universidade Aberta

Ana S. Moura, University of Porto

Giulia Mura, Università Degli Studi di Milano-Bicocca

Gabrielle Murray, RMIT Univeristy

Gundeea Narrainen, University of Mauritius

Annie W.Y. Ng, Hong Kong University of Science and Technology

Nikos Ntavos Cluster of Bioeconomy and Environment of Western Macedonia

María Isabel Núñez Peña, University of Barcelona

Paul O’Leary, Waterford Institute of Technology

Cesar Ortega-Sanchez, Curtin University

Valentina Pagani, CISRE, Cà Foscari University fo Venice

Ayanda Pamella Deliwe, Nelson Mandela University

Maria Isabel Pardo Baldoví, Universitat de València

Cristina Pardo García, Universitat de València

Bartolomé Pascual Fuster, Universitat de les Illes Balears

Preeti Patel, London Metropolitan University

Dieter Pawelczak, Universitat der Bundeswehr Muenchen

Priyeshni Peiris Perera, University of Visual & Performing Arts

Úrsula Pérez, Ampere Energy

Jesus Perez Dasilva, University of The Basque Country

Adamaria Perrotta, UCD

Margarida Pinheiro, Universidade de Aveiro

Rosalina Pisco Costa, Universidade Nova de Lisboa

Antonella Poce, University of Modena and Reggio Emilia

Dimitri Prandner, Johannes Kepler University of Linz

Natalija Prokofjeva, Riga Technical University

Tomi Raassina, Salo Tech Ltd

Justin Rami, Dublin City University

Mario Ramírez, Universidad de San Carlos de Guatemala
Càndid Reig Escrivá, Universitat de València
Marta Retamosa Ferreiro, Universidad de Castilla-La Mancha
Martijn Rietbergen, University of Applied Science Utrecht
Elina Riivari, University of Jyväskylä
Clementina Rios, Universidade do Porto
Iñigo Rodríguez, University of Almería
Marta Rojo Arce, University of Burgos
Alina Romanovska, Daugavpils University
Carlos Jesus Rosa Jiménez, Universidad de Málaga
Birgit Rösel, OTH Regensburg
Angelique Ruiter, University of Applied Science Utrecht
Daniel Sampaio, IPMAIA – Instituto Politécnico da Maia
Juan Antonio Sánchez Serrano, IES Antonio Navarro Santafé, Villena
Jessica Sandland, Massachusetts Institute of Technology
Sirats Santacruz, Mondragon Unibertsitatea
Antoinette Schembri, University of Warwick
Corinne Scicluna, University of Malta
Vicente Sebastián Alapont, Grupo Etra
Semih Severengiz, Bochum University of Applied Sciences
Olena Shliakhovchuk, Universitat Politècnica de València
Aleksandrs Skvorcovs, RISEBA University of Business, Arts and Technology
Oscar Smeets Roc Midden Nederland
Stephan Sommer, Bochum University of Applied Sciences
Noelia Ángel Soriano Regional General Directorate of Vocational Training (GVA)
Dimitrios Stimoniaris, University of Western Macedonia
Asya Stoyanova-Doycheva, University of Plovdiv

Conradus Suhre, University of Groningen

Fátima Suleman, Instituto Universitário de Lisboa (ISCTE-IUL), DINAMIA'CET

Hong Tao, Hong Kong University of Science and Technology

Maria Teresa Tascon, University of León

Orlanda Tavares, A3ES

Tatjana Titareva, RISEBA University

Tobi Thompson, Northeastern State University

Vicente Ramon Tomas Lopez, Universitat Jaume I

Pedro Fresco Torralba, AVAESSEN

Ana Cristina Torres, Universidade do Porto

Martha Liliana Torres Barreto, Universidad Industrial de Santander

Dragos Truscan, Åbo Akademi University

Teemu Tuomela The Raisio Regional Education and Training Consortium

Emma Arianna Manuela Turian, Northeastern Illinois University

Gorka Unzueta, Mondragon Unibertsitatea

Mara Valente, University of Roma Tre

Yorrick Van Bree, Katapult

Frans Van den Akker, Royal Haskoningdhv

Tess Van der Hoek, Katapult

Lenny Van Onselen, University of Applied Science Utrecht

Eneko Jokin Uranga Santamaria, University of The Basque Country

Elisabetta Venezia, University of Bari Aldo Moro

Guilherme Victorino, Universidade Nova de Lisboa

Cristina Vilaplana-Prieto, University of Murcia

Domenico Vito, Università degli Studi di Pavia

Inta Volodko, Riga Technical University

Zuzana Vranayová, Technical University of Kosice



Conference on Sustainable Energy Education – SEED 2024
Valencia, Spain, 3 - 5 July 2024

Olli Vuorinen, RASEKO

Domenik Wolff-Boenisch, Curtin University

Jennifer Wood, Prifysgol Aberystwyth University

Angela Wright, Munster Technological University

Katerina Zdravkova, University Ss. Cyril and Methodius

Ana Zorio Grima, Universitat de València

Supporters



**Co-funded by
the European Union**

This project has received funding from the **European Union's EACEA.A – Erasmus+**, EU Solidarity Corps under grant agreement No 101056147



UNIVERSITAT
POLITÈCNICA
DE VALÈNCIA



ADE

Facultad de Administración
y Dirección de Empresas /UPV

**IN
ECO**

UPV SIRVE

 **ENHANCE**

CARPE

Technical Partner



Sponsor



Prologue

This volume contains the selected extended abstracts of the First International Conference on Sustainable Energy Education (SEED 2024) held in Valencia, Spain 3-5 July 2024.

In its first edition, the SEED conference has become the leading forum for lecturers of vocational training and higher education, researchers, policymakers, and practitioners to exchange ideas and experiences and tackle the challenges of the energy transition to facilitate well-equipped learners, students, professionals, and suitable labor capacity in an environment in which technologies constantly evolve.

During the conference, the partners have co-created and increased not only regional cooperation but also transnational cooperation. Good practices and innovative approaches for learning with impact have been exchanged in the form of oral and poster presentations and developed in the form of workshops.

The SEED conference was designed as the strategic tool for transnational learning and cooperation of the European-funded project CoVE SEED (Centre of Vocational Excellence – Sustainable Energy Education), focused on providing excellent and innovative education to become a fossil-free energy world.

SEED sees education as an important driver for innovation and growth, agile in adapting to the labor market. The objectives of the conference and ultimately the project are therefore focused on innovative energy education that meets the needs of the labor market: a) Preparing learners, students, and professionals with skills and competencies for the future; b) Empowering regional innovation based on regional needs; c) Upscaling and promote work-based education, and will lead to d) The establishment of an international learning community and e) establishment of Centres of Vocational Excellence (CoVES).

The CoVE SEED project consists of educational providers (EQF level 2-7), working professionals, and policymakers from Spain, The Netherlands, Greece, Germany, and Finland. The result is an international community dedicated to sustainable energy continuously growing by activities such as the SEED conference. and Funded by the European Union. Erasmus+, EU Solidarity Corps under grant agreement No 101056147.

The selection of the scientific program was co-directed by Dr. Elena de la Poza Plaza, Dr. Amparo Blázquez Soriano, Dr. Martijn Rietbergen, Ms. Mariola Guarinos, PhD candidate Evridiki Mantela, and Dr. Semih Severengiz, who led a team of 220 program committee members representing 33 countries in five continents.

Following the call for papers, the conference received 180 extended abstracts and 30 workshops from 35 different countries. At least two program committee members reviewed all the submitted extended abstracts under a double-blind review process. The proposal for workshops was also peer-reviewed by the scientific committee. Finally, 114 extended abstracts were accepted to be presented during the conference:

85 as oral presentations and 29 as posters. All of them are published by the UPV Press in this volume. In addition, 18 workshops were accepted to be hosted during the conference. The assessment and selection process ensures a high-quality program greatly valued by the research and practitioners' communities.

Considering both the origin of the participants and of the program committee members, 53 different countries in total are represented. This demonstrates the great international dimension of the event and how we succeeded in our strategy for transnational learning through the SEED conference.

SEED also featured four Keynote Speakers and one Honored Guest Speaker who overviewed important current topics: Prof. Francisco Beltrán from KTH Royal Institute of Technology in Sweden discussed *the Nordic approach to sustainable energy education*. Dr. Débora Domingo and Dr. Nuria Matarredona from Universitat Politècnica de València, Msc. Davide Roletto from Climology and Msc. Eugenio Domínguez Amarillo from Hybrid Energy Storage Solutions Ltd. discussed *Priorities for Sustainable Energy Education*. The session was moderated by SEED Honored Guest Speaker Prof. Dr. Edward. S. Rubin from Carnegie Mellon University.

The conference was hosted by the Faculty of Business Administration and Management of the Universitat Politècnica de València, ranked as the best technical university in Spain by the Academic Ranking of World Universities (ARWU) since 2018. Valencia is a city of culture and heritage. It is the third largest city in Spain, and its location on the shore of the Mediterranean Sea provides its citizens and visitors with privileged weather.

The organizing committee would like to thank our supporters and sponsors, especially Istobal who made this conference a great success. Also, thanks are indebted to the invited speakers, authors, program committee members, reviewers, session chairs, presenters, supporters, and all the attendees.

Our final words of gratitude must go to the Faculty of Business Administration and Management of the Universitat Politècnica de València for supporting and making it possible to become a great event.

Elena de la Poza Plaza
Amparo Blázquez Soriano
Ruijing Wang
Annamaria Sereni

Scientific Editors

List of workshops

- 1. Enabling the flow of knowledge for the Energy and Hydrogen Transition**
Chairs: Marsha Wagner, Jan Geurt van Kessel, Pim Opraus and Yvette Lanting
Organizations: Energy Innovation NL, GroenvermogenNL, HAN University of Applied Sciences
- 2. Sustainable Energy Education: Delivering the energy workforce of the future**
Chairs: Mascha Moorlach and Jacqueline Garcia
Organization: Transforming Energy Access – Learning Partnership (TEA LP)
- 3. ESExNBS@NEB - Exploring Sustainable Education implementing the Nature-Based Solution in the New European Bauhaus perspective**
Chairs: Elena Mussinelli and Ellie Mavroudi
Organizations: ENVI-Reg Observatory (Politecnico di Milano) & Cluster of Bioeconomy and Environment of Western Macedonia (CluBE)
- 4. MINDS – Meaningful Immersive Narratives Driving Sustainability**
Chairs: Karolien Van Riel and Rob De With
Organization: AP Hogeschool Antwerpen
- 5. Game-based Learning for Sustainability in Management Education (GAME-SME)**
Chairs: Fabio Nonino, Luca Fraccascia and Mirko Giagnorio
Organization: Sapienza University of Rome
- 6. Empowering Through Education: T-Shore's Approach to Wind Turbine Technician Training (T-shoreEdu)**
Chair: Gerben Huiszoon
Organization: The T-shore Project partners
- 7. Build your own LEAF: Learning Ecosystem Taking Action for the Future**
Chairs: Linette Bossen and Saskia Postema
Organization: Delft University of Technology
- 8. Sustainable Business Models in practice: a business game competition (BG-COMP)**
Chairs: Fabio Nonino, Luca Fraccascia and Mirko Giagnorio
Organization: Sapienza University of Rome
- 9. Unlocking African green hydrogen potential for mutual benefit cooperation with Europe**
Chair and organization: JUST GREEN AFRH₂ICA consortium

- 10. Unveiling Training and Skill Requirements for Driving the Adoption of Emerging Technologies in the Renewable Energy field - RE-SKILLS Workshop**
Chair and organization: LOMARTOV
- 11. Attract and train European technicians in Energy Transition**
Chairs: Gregorio Blanco Sáez and Anabelle Moriceau
Organizations: Centro de Formación Profesional XABEC & Smart Energy Systems Campus
- 12. Transforming Sustainable Energy Education (TranSEED)**
Chairs: Jan Lauwerijssen, Carme Huguet, Fernando Pascual Fuentes and Julian Mateo Muñoz
Organizations: The Netherlands ROC Midden Nederland, The Netherlands Environmental Science and Sustainability group, IE University, School of Science and Technology, IE University, Spain GVA & IES Alto Palancia, Segorbe (Castellón) – CFSRE Higher Cycle of Renewable Energies.
- 13. Applied and Innovative Research within VET Education for the Energy transition**
Chairs: Barbara van Ginneken, Prof. Dr. Henning Klaffke, Dirk de Wit and Miriam Korstanje
Organizations: The project partners of the AIRinVET project (ISSO, BHH, Katapult network and CoP of the Erasmus+ CoVE)
- 14. H₂ VIRTUAL TRAINING**
Chairs: Dr. Michel Galaup, Dr. Maria Gonzalez Martinez, Pr. Pierre Lagarrigue, Dr. Valérie Lavergne Boudier and Dr. David Panzoli
Organization: Institut National Universitaire Champollion
- 15. Facilitating upliftings in solar energy storage (FUSES)**
Chairs: Úrsula Pérez Ramírez
Organization: Ampere Energy
- 16. Challenges of International Master Degree Courses in Renewable Energy Systems**
Chairs: Andreas Wolf
Organization: Vela Solaris AG (Winterthur, Switzerland)
- 17. Explore integration of sustainability in education from a reflexive, SDG and entrepreneurship perspective**
Chairs: Lenny van Onselen and Sofia Pouri
Organizations: HU University of Applied Sciences & CLuBE
- 18. Accelerate matchmaking in a network: what can we learn from trees and computers?**
Chairs: Frans van den Akker and Eugene Zaaijer
Organizations: Royal Haskoning DHV & Hogeschool Utrecht

Index of communications

Track 1: Teaching and Learning on Sustainable Energy Education

Agroecology and Energy Sustainability at IES “Las Norias”: A Solidarity Project for the Most Vulnerable Families	1
<i>Cristóbal Sánchez Lozano, Gabriel Giménez Cisilino and Rubén José Ferrández Ballester</i>	
Using heat-loss in buildings as a concept to foster sustainability and systems thinking in students	9
<i>Lorenzo Galante, Irina Mancheva, Stefano Fantucci and Valentina Serra</i>	
Analysis of the contribution to sustainable energy training of the degrees taught at the ETSII of the UPV.....	18
<i>Jose Felipe Villanueva López, Ana Valles Lluch, Andrés Lapuebla Ferri, Ana Estesó Álvarez, Sergio Gallardo Bermell, María Sancho Fernández and Angel Ortíz Bas</i>	
Escaperoom in energy education.....	25
<i>Joost Jongen</i>	
Aeromimetics.....	34
<i>Juan Antonio Sánchez Serrano</i>	
A full integrated teaching method. The experience of a postgraduate master’s degree in building energy efficiency design	42
<i>Matteo Iommi, Angelo Figliola, Nico Monteferrante and Giuseppe Losco</i>	
EnerGPT – Enhancing Energy Literacy Education by Customizing ChatGPT	52
<i>Thimo Schulz, Kim K. Miskiw, Christina Speck and Christof Weinhardt</i>	
Stimulating Metering Applications based on Renewables Technologies: presenting the SMART Project.....	62
<i>Vasiliki Kotoula, Christina Panagiota Malliou, Evangelia Rigati, George Chatzargyros, Dimitrios Stimoniaris and Dimitrios Tsiamitros</i>	
Teaching and Learning of Renewable Energy in Remote and Dispersed Pacific Islands	71
<i>Sekove Vodo and Ramendra Prasad</i>	
Digital educational tool on energy efficient retrofitting of buildings	79
<i>Jose Alberto Diaz Angulo, Silvia Soutullo Castro, Maria Nuria Sánchez Egido and Emanuela Giancola</i>	

Upskilling of automotive engineers into electric and hybrid vehicles engineers in Greece	88
<i>Georgios Tsiranidis, Theocharis Xenitopoulos, Dimitrios Tsiamitros, Dimitrios Stimoniaris, Margarita Vatista, George Scroubelos, Theofano Kollatou, Athina Krestou, Ioannis Lamprakakis and Andreas Maropoulos</i>	
Upskilling and Reskilling on H₂ technologies: The Green Skills for Hydrogen Project.....	97
<i>Athanasia Ioannidou, Ioanna Mikrouli, Evridiki Mantela, Eleni Papista and Nikolaos Ntavos</i>	
Energy-Campus Feuchtwangen: Sustainable energy education for supporting decarbonization in semi urban areas.....	105
<i>Haresh Vaidya and Kanav Bhalla</i>	
Solar energy and efficiency at IES El Cabanyal.....	112
<i>Ramon Soria, David Sornosa and IES El Cabanyal</i>	
Towards a more sustainable university campus: the case of ETSII LivingLab at Universitat Politècnica de València (Spain).....	120
<i>Carla Montagud Montalvá, Javier Sanchis Saez, Javier Soriano Olivares, César Pagani Quiroga, Guillermo Escrivá Escrivá and Raúl Simarro Fernández</i>	
Teaching and Learning of Microgrids for Secondary School Learners – a Renewable Energy Sustainability Strategy for East African Communities	128
<i>Paul Bogere, Alexander Belov and Katrin Temmen</i>	
Facilitating evaluation and innovation of regional centers of vocational excellence in sustainable energy education.....	137
<i>Evelien Ketelaar, Lenny van Onselen, Angélique Ruiter and Yvette Lanting</i>	
Context-Sensitive Multidisciplinary Curriculum for Sustainable Energy Access Education.....	146
<i>Ogheneruona Diemuodeke, Tobinson Briggs and Mohammed Ojapah</i>	
Energy poverty training awareness in vocational and technical education	153
<i>Sofia Natalia Boemi, Stavros Spyridakos, Stefania Zourka, Evridiki Mantela, Stefanos Dodouras, Nikolaos Ntavos and Ioannis Fallas</i>	
Challenge-based control education in a master module of renewable energy systems	161
<i>Georg Pangalos, Carlos Cateriano Yáñez, Timon Kampschulte and Gerwald Lichtenberg</i>	

Development of Practical Research-Led Teaching Activities Using a Low Carbon Heating and Storage System169

Robert Barthorpe

Renewable Energy Management Education: Case Study of Birzeit University176

Ahmed Abu Hanieh

Track 2: Partnerships, Collaboration on Sustainable Energy Education

Project-based education: Business assignment manual184

Jan Lauwerijssen

S3 INDUSTRIA: A collaboration project between vocational education training and industrial sector193

Ramon Díaz, Aina Casabán, Lorena Muñoz, Elisa Adell, Paula Guillén and María José Sales

Exploring partnerships between universities, industry and governments to integrate Sustainable Development Goals 202

Konstantinia Nikolaidou, Sofia Pavlidou, Ioannis Karagiannis and Lefteris Topaloglou

The role of universities and civil society’s engagement in fostering entrepreneurship in energy transition and climate change..... 211

Sofia Pavlidou, Konstantinia Nikolaidou, Lefteris Topaloglou and Rafaella-Eleni P. Sotiropoulou

Enabling the flow of knowledge for the Energy and Hydrogen Transition 220

Marsha Wagner, Jan Geurts van Kessel and Rob de Jeu

Broadening horizons, sustainable development in education..... 230

Ramon Soria, David Sornosa and IES El Cabanyal

Fighting Energy Poverty through multi-level energy education: the “Citizen School for the Right to Energy” in the City of Valencia (Spain) 237

Noemi Garcia-Lepetit, Claudia Ferre, Pilar Jorda, Elena Rocher, Belén Costa-Ruiz, Sara Igual, Arturo Zea, Corentin Girard, Jorge Valls, Victoria Pellicer-Sifres and Pepa Ambrosio-Albala

Valorisation of the Renewable Energy Capacity Building in Kenya246

Dr. Francis Xavier Ochieng, Joseph Ngugi Kamau and Ephantus Kamweru

Environmental and Energy Management Systems (EEnMS) in Salesian Educational Institutions in Ecuador.....	261
<i>Xavier Serrano-Guerrero, John Calle-Siguencia, Pablo Arévalo-Moscoso, Fernando Pesantez-Avilés and Juan Cárdenas-Tapia</i>	
Understanding VET skills needs for enhancing the energy transition	270
<i>Martijn Rietbergen and Aleksí Heínonen</i>	
Zero Time, Zero Investment: Innovative Strategies for Sustainable Energy Development in Underdeveloped Countries	279
<i>Aleena Ahmad, Kiran Siraj, Muhammad Arslan Malik, Hafiz Owais Ahmad Khan and Naveed Arshad</i>	
Sustainable Mobility	290
<i>Matias Sanchez García, Carlos Llorca, Carlos Hernández Vicente, Mercedes Llorens Nicolau and Daniel Francés Belda</i>	
Discoveries from a Skills Evaluation on Sustainable Energy in Western Macedonia, Greece	297
<i>Stefanos Gerardis, Athina Krestou, Stergios Maropoulos, Alkiviadis Tsamis, Adam Stimoniaris, Sofia Papanikolaou, Nikolaos Ntavos, Sofia-Natalia Boemi, Stefanos Dodouras and Evridiki Mandela</i>	
Upskilling HVAC technicians on heat pump technologies for green energy transition	307
<i>Elisa Peñalvo-López, Vicente León-Martínez, Mar Cañada Soriano and Iván Valencia Salazar</i>	
Romania on the path of energy transition - from European projects to citizens' perception	315
<i>Marinela Istrate</i>	
Exploring Local Solutions to Address Energy Access Deficit for Off-grid Communities in Nigeria Through Collaborative Learning	324
<i>Misbahu Ladan Mohammed, Aminu Bayawa Muhammad, Abdullahi Muhammad Sokoto, Muhammad Saifullahi Ladan and Zaharadden Muhammad Ladan</i>	
Methodology to Estimate the Decarbonization Potential at the Neighborhood level. Case study: Benicalap, Valencia, Spain.....	332
<i>David Alfonso-Solar, Carlos Vargas-Salgado, Alvaro Manso Burgos, Carla Montagud-Montalvá and Lucía Izquierdo de Andrés</i>	

Empowering Sustainable Futures: Integrating Experiential Learning in Energy Education Through LUMS-UoB Exchange Program.....	340
<i>Kiran Siraj, Munawwar Ali Abbas, Nauman Zaffar and Naveed Arshad</i>	
Enhancing the relevance of vocational training for roofers with the new Sustainable Roofing Methods	350
<i>Elisa Peñalvo-López, Carla Montagud Montalvá, Vicente León-Martínez and Iván Valencia Salazar</i>	
Entrepreneurial Ecosystem in Higher Education: A Systematic Insights for Sustainable Energy Engineering Education at the University of Port Harcourt	359
<i>Tobinson Briggs and Ogheneruona Diemuodeke</i>	
Fostering Sustainable Future: Inter Institute Collaboration, Industry Linkage & Entrepreneurship skills in Higher education	368
<i>Ale Imran, Mohd Rihan, Jay Prakash Singh and Vikrant Sharma</i>	
Guiding Policy Communication: Tailoring Energy Education to Diverse Public Sentiments	378
<i>Christina Speck, Philipp Fritz, Christof Weinhardt and Jonas Fegert</i>	
Crossing Boundaries in Sustainable Energy Education: Transnational Learning is a Two-way Street	387
<i>Lenny van Onselen, Evelien Ketelaar, Angelique Ruiten, Esther Wijma and Martijn Rietbergen</i>	
Collaborative Innovation in Energy: Integrating Design Thinking for Sustainable Product Development	395
<i>Guilherme Victorino</i>	
Sustainable Planning for the Development of Site-Specific Run-Of-River Hydropower: A Case Study in the Gonovo River Catchment, Finschhafen District, Papua New Guinea.....	403
<i>Tingneyuc Sekac, Nosare Maika, Sujoy Kumar Jana, Ora Renagi, Sammy Aiau and Dapsy Olatona</i>	
Knowledge dissemination and diffusion towards regional ecosystems	413
<i>Frans van den Akker, Jorrit Bock and Fionna Heuff</i>	
Collaborative Reskilling: The Partnership of Hellenic Electricity Distribution Network Operator and University of West Macedonia, Greece, in Advancing Smart Electricity Grids	421
<i>Evangelos Boutsiadis, Kimon Koulierakis, Dimitrios Tsiamitros, Dimitrios Stimoniaris, Theofano Kollatou, Athina Krestou and Konstantinos Karamarkos</i>	

Track 3: Governance & Funding for Sustainable Energy Education

European Initiatives for Professional Excellence in Fossil Free Energy Production..... 430
Athina Krestou, Alkiviadis Tsamis, Stefanos Gerardis, Stergios Maropoulos, Adam Stimoniaris, Fokion Papathanasiou, Konstantinos Karamarkos, Sofia Papanikolaou, Andreas Maropoulos and Fotios Tsampouris

Techno-Economic Evaluation of Flexible Technologies for Renewable Energy Communities..... 439
Álvaro Manso Burgos, Isabel Aparisi Cerdá, David Ribó Pérez and Tomas Gomez-Navarro

The comprehensive and unified approach to financing and developing sustainable energy education in Ukraine..... 447
Halyna Matviienko and Svitlana Kucherkova

Towards Sustainable Academia: Unveiling Trends and Challenges in University Energy Education in Zimbabwe..... 456
Bright Chisadza and Keith Phiri

Track 4: Sustainable Education

How can we teach sustainability? Active learning based on an experimental game 465
Sabrina Fontanella, Luca Fraccascia, Fabio Nonino and Alessandra Scarnicchia

Beyond Digital Survival... Student Resilience and Acceptance of On-line learning in France 473
Nada Mallah Boustani, Loubna Mourtaji and Nathalie Chiss

Innovating for a sustainable future 483
Mónica María González Cabrera

Field classes in accounting as a "Black Swan" of sustainable education 493
Magdalena Majchrzak and Piotr Szczypa

Education for Sustainable Development in Baltic Universities..... 501
Dina Bērziņa

Exploring a quantification method of the Whole School Approach with regard to climate action..... 510
Lena Tholen, Frank Labunski, Oliver Wagner, Maike Venjakob and Sebastian Albert-Seifried

A Study on SDG Awareness in Computer Science Curricula.....	518
<i>Vicente R. Tomás, Sandra Catalan Pallarés, M^a Isabel Castillo and Germán León Navarro</i>	
Integrating Service-Learning and Sustainability into the Engineering Curriculum: A Waste Management Case Study.....	527
<i>María Linares Serrano, Ines Moreno García and M. Isabel Pariente Castilla</i>	
Emerging Tech for Future Experts: Unleashing the Potential of Generative AI in Sustainable Education	535
<i>Dragan Vukmirovic, Tijana Comic, Nebojsa Stanojevic and Uros Milicevic</i>	
Promoting Energy Sustainability in ICT.....	543
<i>Consolación Gil, Fernando Martínez, Jorge Ventura, Viktor Isanbaev, Raúl Baños and María G. Montoya</i>	
Campus decarbonization challenge learning experience.....	552
<i>Raquel Martín López, Maria Calero Pastor, Carla de Paredes Gallardo, Hector Espinos Morato, Maria Luz Martínez Musoles and Sofia Garcia Manglano</i>	
LLARS application: changing lives from download to download.....	561
<i>Alba Álvarez Tormos, Joan Aparicio Navarro, Stella Bayona Sedeño, Cristina Catalán Lario, Jesús Comos García, José Manuel Gómez Maestre, Madalina Ionela Grigore, Érica-Alejandra Ivars Bernabeu, Santiago Guillermo Martínez Lozano, Rubén Merino Cantos, Lucia Monzón Barquero, Adriana Moreno González, Javier Navarro Bellver, Luisa Fernanda Robayo Julio, Iris Sánchez Orts, Marcel Sanz Serra, Alba Soler Espí and Silvia Aja Martínez</i>	
Learning Cooperations as a Method to integrate Education for Sustainable Development into Further Vocational Education	570
<i>Thomas Spelten, Désirée Rottmann and Semih Severengiz</i>	
BIM₄CLIMATE: Project-Based Learning to enhance students engineering skills within a CampusLab.....	580
<i>Blanca Tejedor Herrán, Maria Sande Nogueira Dos Santos Sampaio, Núria Forcada Matheus, Francesc Trisan Seguí, Aleix Rifà Beltran, Paula Gordo Gregorio and Marta Gangolells Solanellas</i>	
Empowering Amazonian Communities Through Environmental Education and Technology	589
<i>Carme Huguet, Alba Avila and Daniela Alvarez-Gallo</i>	

Being effective when talking about Climate Change: an experience from the University of Trento (Italy).....	597
<i>Maria Cantiani</i>	
Designing Courses & Increasing Learning Motivation through Gamification	603
<i>Kim Möller and Thomas Spelten</i>	
Implementation of Adaptive Training in Higher Mathematics at Riga Technical University	612
<i>Inta Volodko and Sarmite Cernajeva</i>	
Health Screening & Physical Education Surveillance for Different Types of Students	621
<i>Florin Mostoflei</i>	
Gender equality in the clean energy transition: implementation of an academic toolkit in Bilbao School of Engineering (UPV/EHU)	630
<i>Sara Rozas, Natalia Alegría, Saioa Herrero and Paula Serras</i>	
Education for sustainability in a secondary and vocational training center	638
<i>Elisa Adell</i>	
Development of a 3D virtual world tool for sustainable energy education	646
<i>Marta Guerra-Mota, Michalis Xenos, Maria Manuel Sá and Minas Dimosthenis</i>	
Empowering SMEs for Business Growth.....	655
<i>Anna Ollanketo, Mervi Rajahonka and Heli Saali</i>	
What is the best way to communicate with students? An ordered logit regression approach for the study of communication between e-tutors and students in an Italian online University	664
<i>Giorgio Cecchi, Andrea Nardi and Massimiliano Naldini</i>	
Failures of Education Policy Reforms to Address Climate Change.....	672
<i>Donal Mulcahy and Judith Madera</i>	
Semantic prosody in the field of environment and climate change: a corpus-based analysis	679
<i>Katrin Herget and Teresa Alegre</i>	
OneClickQuiz: Instant GEN AI-Driven Quiz Generation in Moodle	689
<i>Antoun Yaacoub, Siba Haidar and Jérôme Da Rugna</i>	

A Methodological Framework for Survey Design: Investigating Perceptions of Product Sustainability - A Case Study	699
<i>Svenja Hauck, Lucas Greif and Kim Skade</i>	
Assessing digitalization in personnel management: a systematic approach and case study	708
<i>Aleksandrs Skvorcovs and Valērijs Dombrovskis</i>	
Active Blended Learning of Industry 5.0-Oriented Sustainable Power Engineering Specialists	719
<i>Valery Vodovozov, Zoja Raud and Eduard Petlenkov</i>	
Exploring the Affordances of Blockchain Technology to Enable 5R Permissions for Co-Creating OER	726
<i>Bence Lukacs</i>	
Environmental Reports of Power Lines: promoting critical awareness about SDGs and professional ethics among engineering students	735
<i>Zalaa Aginako, Rafael Alberdi and Teresa Guraya</i>	
Renewable Technologies and Active Learning: Boosting Engineering Education through Student Research Groups	743
<i>Luis Sánchez, María Dolores Reyes and Yolanda E-Martín</i>	
Scrollytelling as a Strategy for Socio-Environmental Engagement: A Digital Citizen Science Narrative Approach	751
<i>Jorge Sanabria-Z, Inna Artemova, Jesús Gabriel Félix Mendivil and Pamela Geraldine Olivo-Montaño</i>	
Watershed and Place-Based Environmental Pedagogies	759
<i>Judith Madera and David Phillips</i>	
Reflecting on Addressing Academic Integrity through Authentic Assessment	768
<i>Sharon Lehane and Angela Wright</i>	
Sustainable and solidary experiences in our centre	777
<i>Jose Carbonell Alcañiz, Luz Marina Andreu Plaza, Manuel Hurtado Ferrandez, Maria Isabel Rubio Navarro, Maria Luz Rueda Pérez and Rafaela Ferrer Márquez</i>	
Embedding sustainability in a hierarchical Higher Education system	785
<i>Paul O'Leary</i>	
Emotional Intelligence in Intergenerational Collaboration	793
<i>Juraj Mikuš, Anna Pilková, Miloš Mrva, Jaroslav Hul'vej and Yuliia Fedorova</i>	

Key factors in the responsible consumption behaviour among university students: The case of Universitat Politècnica de València	802
<i>Mónica Martínez-Gómez, César Berná Escriche and Eliseo Bustamante García</i>	
Massive Open Online Courses for Sustainable Urban Development: the RES4CITY approach	810
<i>Álvaro Manso-Burgos, Carla Isabel Montagud Montalvá, Carlos Vargas Salgado, David Alfonso Solar and Rafael Royo Pastor</i>	
Assessing Post-pandemic Energy Literacy among Children: Current Concerns and A Predictive Model based on Social Learning Theory.....	821
<i>Zhichao Lei</i>	
#MiSchoolInTransition: learnings from the adaptation of the EuroNet 50/50 method in educational centres of the city of Valencia (Spain)	838
<i>Paula Martín, Blanca Llavata, Paula Martínez, Eduardo Amer and Corentin Girard</i>	
The ECF4CLIM Ecological Footprint Calculator as an awareness tool to promote more sustainable behaviors in educational centers	848
<i>Ana Rosa Gamarra Rodríguez, Carmen Lago Rodríguez, Yolanda Lechón Pérez and Isabel Preto</i>	
The potential use of infrared cameras to provide a meaningful understanding of thermal science at different levels of education	857
<i>Mar Cañada Soriano, Guillermo Vilariño Feltrer and Rafael Royo Pastor</i>	
Living labs and collaborative initiatives on European university campuses for sustainability learning: SusTIMEability-lab project	866
<i>Carla Montagud Montalvá, Javier Sanchis Saez, Javier Soriano Olivares, Ángel Sapena Bañó, Arantxa Querol Monforte and Elisa Peñalvo López</i>	
Can AI be used to develop an on demand and sustainable feedback system?.....	875
<i>Nazim Ali and Sarah Aynsley</i>	
Learning sustainable building by doing architectural detail models	884
<i>Elena Montacchini and Angela Lacirignola</i>	
Development and sustainment in an Australian education context: Centring Indigenous Knowledges	892
<i>Gabrielle Murray</i>	
Principles guiding a South-South capacity development teaching collaboration.....	899
<i>Monique Kevvy</i>	

Team projects to promote interest in basic microbiology.....	908
<i>Linda Mezule</i>	
An activity to promote entrepreneurship and sustainable tourism business models for undergraduate students.....	914
<i>Vicent Caballer-Tarazona and Maria Caballer-Tarazona</i>	
Pedal for your future	919
<i>Nuria Arenas Peiró and Susana Martí Sendra</i>	
Changing individuals, institutions and environmental conditions: an innovative hybrid participatory approach for sustainability in education.....	927
<i>Yolanda Lechón, Ana Prades, Silvia German, Josep Espluga, Markku Lehtonen, Jose Antonio Becerra, Israel Marques, Terhi Nokkala, Hannu Heikkinen, Anna Lehtonen, Niina Mykrä, Ricardo Chacartegui and Ana Rosa Gamarra</i>	
Designing a Massive Open Online Courses (MOOC) for Effective Learning in Electrical Energy Economics and Planning for Engineering Students	936
<i>Nofri Yenita Dahlan and Jefri Dahlan</i>	
Institutional Policies and Higher Education in Sustainability Agenda.....	945
<i>Nikolaos Taousanidis and Andreas Taousanidis</i>	
Sustaining Authentic Assessment (AA): A pilot survey of student perceptions of AA to improve higher order thinking and employability	952
<i>Judy Rose and Adis Duderija</i>	
A study of problem-based learning in higher education with a focus on sustainability degree programmes	961
<i>Semih Severengiz, Stephan Sommer, Michelle Hoffmann and Ann Kathrin Stinder</i>	
Sustainable Education for Business Leaders: Integrating Corporate Social Responsibility (CSR) and Environmental, Social, and Corporate Governance (ESG) in MBA Programs – A Vietnamese Perspective.....	970
<i>Lorena Mathien</i>	
Engaging students in Circular Design: teaching experiences with (future) architects and designers	979
<i>Silvia Tedesco, Elena Montacchini and Nicolò Di Prima</i>	
Sustainable Education in Art and Design Universities: A Teaching Case Emphasizing Materials	988
<i>Ziyu Zhou, Anna Palm and Markus Holzbach</i>	

Engaging students in Circular Design: teaching experiences with (future) architects and designers

Elena Montacchini, Silvia Tedesco and Nicolò Di Prima^a

^aDepartment of Architecture and Design, Politecnico di Torino, Italy

Abstract

In recent years, an increasing number of Architecture and Design Schools are investing in new teaching programs on sustainability and circular economy, considering crucial the training of new professional figures with wide-ranging skills. The paper reports the outcomes of four-year teaching experiences on the topic of circular design with (future) architects and designers, developed as part of the course Designing and Developing the Circular Economy, conducted at the Politecnico di Torino in Italy. The activities that characterize the training course focus on interdisciplinary teaching and learning experiences such as confrontation, learning-by-doing and hands-on activities with a systemic approach. These activities refer to: testimonies of actors working in the social, business and research spheres; "circular" readings derived from the international scientific debate; design sprint and self-construction workshops based on the principles of Reuse, Repurpose, Upcycling, Disassembly; and development of circular economy scenarios in real contexts. These experiences prepare the students to become professionals aware of the challenges of the circular economy, able to reflect critically on the challenges and difficulties relative to the theme, to experience the transformation of matter from waste to resource, to use with confidence tools to activate networks and circular economies at the local scale.

Keywords: circular design; higher education; learning-by-doing.

How to cite: Montacchini, E.; Tedesco, S; and Di Prima, D. (2024) Engaging students in Circular Design: teaching experiences with (future) architects and designers. In proceedings: Conference on Sustainable Energy Education – SEED 2024. Valencia, Spain, 3 - 5 July 2024. 979-987. <https://doi.org/10.4995/SEED2024.2024.19007>

1. Introduction

In recent years, an increasing number of Architecture and Design Schools are investing in new teaching study modules and programs on sustainability and Circular Economy (CE) – such as Delft University of Technology (NL), Aalto University School of Arts, Design and Architecture (Helsinki, FI), Yale School of Architecture (New Haven, USA) and others - considering crucial the training of new professional figures with wide-ranging skills.

The transition to a circular economy produces new challenges for architects and designers, who need to acquire specific skills and competencies on more effective use of resources by closing resource loops and facing complex systems involving different stakeholders (Sumter et al., 2020).

A nascent body of literature documents different higher educational approaches: design studios and workshops (Ryńska, 2020), simulation and serious games (De la Torre et al., 2021), design-teaching activities in the context of financed research project (Wandl et al., 2019).

This paper aims to contribute to the debate on teaching circular design by describing a four-year experience of educational experiments with (future) architects and designers developed as part of the course Designing and Developing the Circular Economy at the Politecnico di Torino in northern Italy.

2. Circular Design educational experiments: methodology and results

The interdisciplinary course presented below was introduced in 2020 at the Politecnico di Torino as an optional module. It involves students with different educational backgrounds from master's degree courses in Architecture and in Design (between 50 and 80 students per academic year), and stakeholders from outside academia.

The course aims to train new professionals with transversal skills that may prefigure circular solutions, steer new processes, connect networks of social and economic actors, so that the waste of one can become a resource for the other. The heterogeneity of students, actors and local realities involved are added values for the learning process.

The activities that characterize the semester-long training are focused on interdisciplinary teaching (between architecture and design) and learning experiences that make confrontation, learning-by-doing and hands-on activities, the systemic vision their strengths. These activities refer to: testimonies of actors working in the social, business and research fields; "circular" readings derived from the international scientific debate; design sprint and self-construction workshops based on the principles of Reuse, Repurpose, Upcycling, Disassembly; and development of circularity scenarios in real contexts.

The course started in conjunction with the Covid-19 pandemic and in the first two years was conducted entirely online. During this period, design sprint and self-construction activities were carried out in collaboration with the Food Design Lab of the Polytechnic University of Turin. We chose to use food as a waste material on which to experiment and household equipment as appropriate technologies. Inspections of the realities with which we developed the circular scenarios were carried out online through photos and video stories (Montacchini, Tedesco, Di Prima, 2021).

2.1 Visions of circular economy

It is not straightforward to confront the topic of CE, defined in the international scholarly literature as an "umbrella-concept" that includes a very broad set of meanings and visions (Kirchherr et al., 2017).

To stimulate and support architecture and design students to build a critical approach on the topic and to approach its different economic, environmental, and social dimensions, it is required to activate debate and confrontation to question different approaches (Friant et al., 2020). In the context of the course, we tried to present and answer the various questions that belong to the EC discourses through discussions with actors and researchers active in the world of the CE and through "circular readings" selected from the international scientific literature.

In particular, the methodology adopted included discussion and interaction with the territory, the experience and visions of very diversified actors invited to answer our questions with an "open" classroom logic. Discussion and debate were also fuelled by the arguments stimulated by reading the selected articles.

For example, new roles and emerging professions for architects and designers have been debated through a series of articles (Dokter et al., 2021; Benachio et al., 2020) and through testimonies of organizations that have already incorporated the principles of circular design in developing products, services, and new materials.

These actors told us about challenges and difficulties in their work, the concrete contribution of their activities in enhancing the transition to a circular economy, the stakeholders they network with, and the tools they use. We wanted to investigate the development of the concept of "sustainability" and "circular economy," capturing their similarities, differences and possible points of convergence (Geissdoerfer, 2017). Or again, as an example, the social dimension of the circular economy was discussed (Hobson and Lynch, 2016).

Testimonials and circular readings helped students develop a multifaceted view of the circular economy, allowed them to bring out strengths and weaknesses of the different approaches,

visions, and goals that characterize the circular economy, and enabled students to position themselves critically with respect to the complexity of the topic.

2.2 Circular design sprint and self-construction workshops

Hands-on activities have long been recognized to be of strategic importance to the learning process in Architecture Schools (Mackintosh, 2014), yet there are still not many examples that combine hands-on experimentation activities with the circular economy theme.

The learning-by-doing and hands-on activities included in the course make it possible to integrate circular economy theory with practice, with the aim of promoting students' creative and problem-solving skills regarding relevant topics such as reuse, repurpose, upcycling, and disassembly of materials and products.

These activities are structured in extemporaneous workshops of limited duration, inspired by the design sprint methodology, a Google Venture process used to solve critical issues through prototyping in a short time (Knapp et al., 2016).

In just 8 hours, students are asked to design and build objects, furniture elements or micro-architectures by being inspired by the available scrap material, which drives the project. Specifically, the work phases are as follows: harvest of available materials and technologies, first cleaning of materials, definition of the project concept, design/prototype realization, prototype revision, finishing work, and project release.

During the workshop that took place in 2022 at “Costruire Bellezza”, a participatory design Laboratory for Social Inclusion and Interdisciplinary Education, the brief assigned to the students was to design and make a toy for the children living in a neighbouring social house starting with wood scraps and old furniture items or portions of them (drawers, doors, chair legs, knobs) found in the “Costruire Bellezza” workshop. Toys of various kinds such as pinball machines, chess boards, table soccer were made. The figure 1 shows a go-kart made from the seat of an old stool, a discarded coat rack, salvaged wheels and scrap wood.

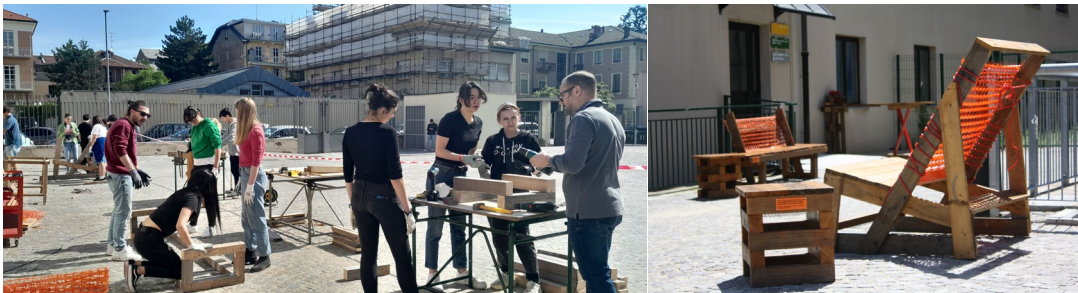
Fig. 1 – Human Powered Go-kart (students a.y. 2021/2022: C. Cavanna, I. Ciminiello, G. Dilauro, E. Ferrari, R. Giachi, S. Nardi)



Source: authors (2022)

In 2023, the workshop was held at LaSTIn, the Politecnico's laboratory for the Development of Innovative Technological Systems. This time, the material came from the scraps of a construction site deposited in the courtyard of the laboratory, and the goal was to make temporary furniture for the courtyard itself. A project by the students and for the students who built tables, benches, chaise longues and stools from construction site nets, discarded pallets, old wooden boards (figure 2).

Fig. 2 – Furniture made from yard waste (students a.y. 2022/23). From left to right, processing steps and finished furniture.



Source: authors (2023)

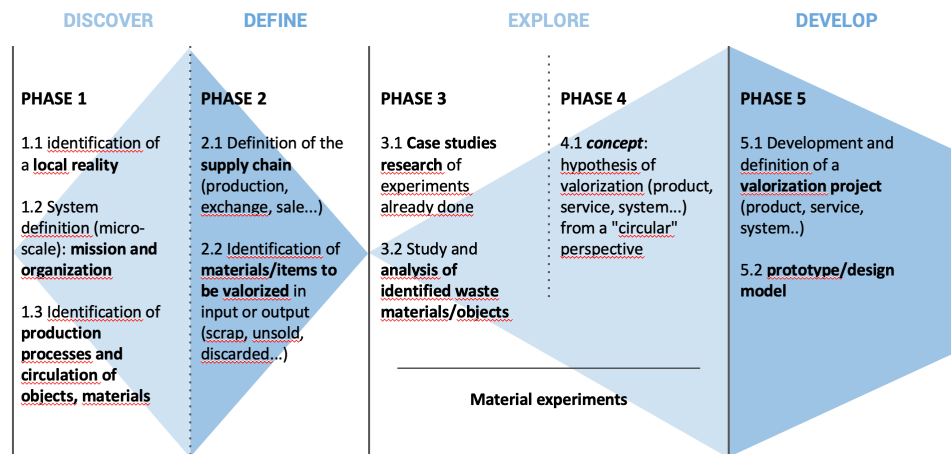
2.3 Circular economy scenarios for the real-world

Theory and practice found a meeting point in the last activity that students conducted during the semester.

The objectives of the "Circular Economy Scenarios" activity were to identify the possibilities of activating circular economy processes within real local organizations and contexts; explore the opportunities for the valorization of materials, products, and waste within "linear" structure and supply chains; and develop a "circular" project proposal that takes into account the specificities of the chosen context from a social, cultural, technological, economic and environmental point of view.

The activities were divided into 5 phases based on the Double Diamond approach proposed by Design Council Uk as shown in figure 3.

Fig. 3 – Diagram of activities based on Double Diamond methodology



Source: authors (2024)

The students, divided into multidisciplinary groups, were tasked with identifying an accessible and willing to be "studied" local reality/organization that manufactures products and/or offers services. The first phase consisted of analyzing the processes of production and circulation of objects and materials in order to be able to recognize any inefficiencies and negative impacts in terms of waste production of the "linear" system supply chain. The second phase aimed to define the main waste products from which to start the circular design process.

In the third exploration and concept phase, students had to assess the potential for waste valorization and develop a project concept based on circularity logic.

The fourth phase consisted of developing a circular economy project for the reality investigated, taking into account real and concrete constraints and possibilities provided by the context and the surrounding area. During this phase, students had the opportunity to prototype the design solutions to verify the feasibility of the project (products, technologies, organizational systems...) and to verify the design proposals through an analytical, creative and experimental approach.

The entities involved were the most diverse with respect to both size and scope: from the food sector (e.g., farms), to the manufacturing sector (e.g., production of textiles, reconstituted stones), to those oriented toward social cooperation (e.g., cultural, educational and social associations).

The outputs produced were concepts, systems projects between actors, and actual prototypes made in the university's laboratories (strawberry picking baskets made from strawberry leaves, bags made from discarded advertising banners, tiles from stone scraps,...).

The concluding phase of the course included an exhibition of the works produced, which enabled students, faculty, companies and organizations 'studied' to network to check and

discuss together the real feasibility of the identified circularity scenarios (figure 4). This stage assesses students' ability to critically and reflectively answer questions regarding the sustainability of their project proposal and possible impacts in economic, environmental and social terms.

Fig. 4 – Exhibition of projects



Source: authors (2022)

3. Conclusions

The experiences described, developed in an interdisciplinary course at the Politecnico di Torino, are part of the debate on teaching circular design to (future) architects and designers. Thanks to the feedback from the students interviewed at the end of the courses, in these years of experience we have been able to ascertain that the integration of theoretical, practical and experiential activities are essential to be able to experience a critical and non-stereotypical view of CE. The proposed teaching model defines three different types of activities that contribute in different ways on training new professionals with wide-ranging skills.

The testimonies from actors of different sectors and the "circular readings" enable students to gain critical insight into a complex topic, grasping limitations and opportunities of the circular economy. The learning-by-doing and hands-on activities included in the course make it possible to integrate circular economy theory with practice and promote creative and problem-solving skills based on challenges concerning waste reduction and second-life possibilities of materials and products. Developing new "circular scenarios" in real-world settings enables strategic skills, such as the ability to design transitions to the circular economy and develop circular products and models.

All activities also enabled the development of interpersonal competencies such as collaboration, participation, empathetic exchange of perspectives, and teamwork abilities.

These experiences prepare the students to become professionals aware of the challenges of the circular economy, to be able to reflect critically on challenges and difficulties relative to

the topic, to experience the transformation of matter from waste to resource, to use with confidence tools to activate networks and circular economies at the local scale.

Acknowledgements

Thanks to all the students (A.Y. 2020/21, 2021/2022, 2022/2023), experts, companies, organizations (M. Cappellini – Matrec; M. Mangione – OffGrid Italia; Pier Andrea Moiso, - Triciclo Scs; S. Giorgi – Politecnico di Milano; D. Dal Palù – MatTO, Politecnico di Torino; M. D’Urzo - Politecnico di Torino) and laboratories (Food Design Lab; Costruire Bellezza - Laboratory for Social Inclusion and Interdisciplinary Education; LaSTIn - Laboratory for the Development of Innovative Technological Systems, Politecnico di Torino) involved in the Circular Design experiences. No funding has been received for the development of the research.

Conflicts of interest

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

References

- Benachio, G. L. F., Freitas, M. D. C. D., & Tavares, S. F. (2020). Circular economy in the construction industry: A systematic literature review. *Journal of cleaner production*, 260, 121046.
- De la Torre, R., Onggo, B. S., Corlu, C. G., Nogal, M., & Juan, A. A. (2021). The role of simulation and serious games in teaching concepts on circular economy and sustainable energy. *Energies*, 14(4), 1138.
- Dokter, G., Thuvander, L., & Rahe, U. (2021). How circular is current design practice? Investigating perspectives across industrial design and architecture in the transition towards a circular economy. *Sustainable Production and Consumption*, 26, 692-708.
- Friant, M. C., Vermeulen, W. J., & Salomone, R. (2020). A typology of circular economy discourses: Navigating the diverse visions of a contested paradigm. *Resources, Conservation and Recycling*, 161, 104917.
- Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy—A new sustainability paradigm?. *Journal of cleaner production*, 143, 757-768.
- Hobson, K., & Lynch, N. (2016). Diversifying and de-growing the circular economy: Radical social transformation in a resource-scarce world. *Futures*, 82, 15-25.
- Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, conservation and recycling*, 127, 221-232.
- Knapp, J., Zeratsky, J., & Kowitz, B. (2016). *Sprint: How to solve big problems and test new ideas in just five days*. Simon and Schuster.

- Mackintosh, L. (2014). Just doing it: The role of experiential learning and integrated curricula in architectural education. *The International Journal of Pedagogy and Curriculum*, 20(3), 67-78.
- Montacchini, E., Tedesco, S., & Di Prima, N. (2021). Progettare e sviluppare l'economia circolare. Un'esperienza didattica sulla trasformazione di rifiuti in nuove risorse per l'architettura e il design. Anteferma.
- Ryńska, E. (2020). Design workshops and the circular economy. *Global Journal of Engineering Education*, 22(1).
- Sumter, D., de Koning, J., Bakker, C., & Balkenende, R. (2020). Circular economy competencies for design. *Sustainability*, 12(4), 1561.
- Wandl, A., Balz, V., Qu, L., Furlan, C., Arciniegas, G., & Hackauf, U. (2019). The circular economy concept in design education: Enhancing understanding and innovation by means of situated learning. *Urban Planning*, 4(3), 63-75.