

Learning sustainable building by doing architectural detail models

Original

Learning sustainable building by doing architectural detail models / Montacchini, E., Lacirignola, A.. - ELETTRONICO. - (2024), pp. 884-891. (First International Conference on Sustainable Energy Education – SEED 2024 València (ESP) 3 - 5 July 2024).

Availability:

This version is available at: 11583/2992975 since: 2024-10-01T13:37:40Z

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, AVAESEN

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 Kritzing, 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 Esteso 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 Ruiter, 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>Evangoulos Boutsiadis, Kimon Koulirakis, 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>	

Learning sustainable building by doing architectural detail models

Elena Montacchini^a, Angela Lacirignola^a

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

Abstract

The paper presents the outcomes of an experimental didactic activity aimed at developing three-dimensional architectural details models starting from the exploration of "zero cost" materials and products. This activity was proposed to students in the first year of the degree course in Architecture at Politecnico di Torino, as part of the course Culture and Fundamentals of Architectural Technology.

By considering the building as the set of spatial and technical elements characterised by their function and relationships, the process of architectural detail modelmaking allows students to understand the functional roles of the different building components, and to explore how different elements and materials integrate to realize a sustainable and energy-efficient building.

Furthermore, the choice of using waste or recycled materials has brought the students closer to sustainability issues, in particular focusing on material recovery and the circular economy. The students creatively explored the 'zero-cost' materials available to them, selecting those that visually or tactically aligned with the characteristics of the architectural element they intend to model.

The models were collected in a book. The result is an unusual open access catalogue of architectural details easy to understand, made by architecture students for architecture students.

Keywords: architectural technology; technical element models; sustainable building; learning by doing.

How to cite: Montacchini, E.; Lacirignola, A. (2024) Learning sustainable building by doing architectural detail models. In proceedings: Conference on Sustainable Energy Education – SEED 2024. Valencia, Spain, 3 - 5 July 2024. 884-891. <https://doi.org/10.4995/SEED2024.2024.19007>

1. Introduction: hands-on activity and modelmaking as learning tool

In this increasingly digitized world, physical models still play a strategic role in teaching architectural design and architectural technology. There are several benefits: from providing a tactile and interactive experience that helps the creative process flow, to contributing a better understanding of scale and proportion, and enabling exploration of a building's structural systems, components and material.

In several national and international schools of architecture, the hands-on activity of physical prototyping is a well-established and widely practised activity, and the learning-by-doing approach is considered a distinctive element in the teaching process (Paris, 2017).

A learning by doing approach has been adopted for several years by the Architecture Technology research group of the Politecnico di Torino. In collaboration with the Laboratory of Innovative Technological Systems (LaSTIn), the research group conducts many experiences where the development of prototypes plays a key role, intended both as a learning tool and as a research and experimentation tool (Fasano et al., 2023).

However, students generally develop their technology model at the end of their course of study, or even at the time of the dissertation if this is of an experimental nature and uses prototyping as a research tool. Instead, the paper describes an experience that aimed to explore the possibility of introducing architectural modelmaking in the first year as a real learning tool (Eppinger and Ulrich, 2012) (Mayuk and Coşgun, 2020).

Students thus had the opportunity to use the model not only to represent compositional and typological choices, but as a tool to study in an experimental way the features of materials, components and construction systems and their interrelation in the building system. The aim is to train the skills and competences needed to identify the criteria for choosing between alternative technical options during the design phase of a sustainable building, according to a Hands-on Learning Experience approach (Yildirim et al., 2014; Pak and De Smet, 2022).

2. How to build models: an experiential working methodology

The didactic experimental activity aimed at developing three-dimensional models of architectural details is part of the activities we carried out within the Culture and Fundamentals of Architectural Technology course in the first year of the Architecture degree program at Politecnico di Torino. The course intends to provide students with an initial framework of theories, methods and tools useful for understanding and learning how a sustainable building is made.

The course includes lectures on architectural technology, meetings, seminars and practical activities. Meetings and seminars make it possible to collect direct testimonies from designers, companies and experts in the construction sector enabling deeper exploration of

specific topics by gaining knowledge, skills and experiences. Practical activities, such as visits (virtual and physical) to materials libraries, construction sites and companies, help students to understand material, technological and performance features of building elements, as well as how materials and building components are connected, combining theoretical study with the observation of objects and their manipulation. A series of exercises on the analysis, comprehension and graphical representation of technological systems completes the training course.

In this context, modelmaking of technological details fits in. The idea of assigning this type of exercise, linked to the concepts of learning by doing, arose during at the special moment of the pandemic - when teaching was conducted exclusively remotely - to provide students with the opportunity to engage in a hands-on activity. Working with waste materials, using what you have 'at hand' without the need to buy specific materials, had the advantage of placing all students in the same conditions. Furthermore, the choice to use waste or recycled materials brought students closer to sustainability issues, in particular concerning material recovery and the circular economy. Packaging, textile waste, household items, food packaging are materials that are available and accessible to everyone, and can be processed with low-tech technologies that we all have, such as glue, tape, scissors.

The students were asked: to identify a technical element of the building envelope; to creatively explore 'zero-cost' materials available to them, selecting those that visually or tactically aligned with the characteristics of the element to be modelled; to develop a three-dimensional model, on a proportional scale, highlighting materials and components.

Different approaches were employed to develop models, resulting in a wide variety of solutions: all-round, embossed, single-material or prevalent material models, of different sizes. Some students paid particular attention to packaging, graphic composition and model presentation. The exercise was developed individually and independently. During the final exam, the model presentation facilitated discussion on sustainability issues and validated understanding of the functional roles of the different materials and components that characterize the building system and the principles of energy efficiency.

3. Architectural detail models

Each student chose the detail to model from those discussed during theory lessons and graphically explored in previous drawing exercises.

These are the main technical elements of the building envelope that determine thermal exchanges with the surrounding environment and therefore the energy efficiency:

- Foundation Systems, in particular ground floor with ventilated cavities;

- various alternatives of the Wall Systems (brick wall, dry-built wall, e.g.) and their connections with the Floor Systems;
- Roof Systems with the different technical solutions of flat, green or pitched roofs.

The models were catalogued specifying for each one: the technological system and elements, the different functional layers represented, the size and the list of 'zero cost' materials used.

Some of the most commonly used materials were: packaging materials, such as cardboard, bubble wrap, polyethylene sheets; scraps from other modelling activities, such as Laminil or vegetable cardboard cuttings; materials and objects commonly found at home, such as different types of sponges, coffee capsules, gauze, surgical masks, caps, cloth.

These waste materials took on different functions within the various models, depending on the different material interpretations given by the students. For example, dish sponges represented insulation material well, but when appropriately coloured, they also became the substrate of a green roof; egg cups were used as formwork for the ventilated crawl space in the ground floor, but also as a draining layer of the green roof.

3.1 Foundation Systems

The Foundation Systems section encompasses a variety of technological solutions related to the building's connection to the ground. The most frequently represented solution is the ground floor with a ventilated crawl space with disposable formwork. Egg cups, plastic bottle bottoms and biscuit containers were useful waste materials used to represent disposable polypropylene formwork; paper and plastic straws, along with various types of tubes, well represented ventilation pipes for the ventilation of the crawl space; foam rubber and corrugated cardboard were assimilated as insulation materials.

Fig. 1 – Foundation System Model (Card n. 002 - Open Access Catalogue)



Source: Lacirignola and Montacchini, 2023

3.2 Wall Systems and Floor Systems

The models in this section represent different technological alternatives of external walls and intersection details between the wall systems and floor systems.

Different types of walls were explored: brick walls with external, internal or cavity insulation, x-lam panel walls, wood-framed systems, ventilated facades; combined with traditional brick slab solutions or more innovative steel or x-lam solutions.

Hydrophilic cotton, dish sponges, Plumbers Hemp, all represent insulation materials with different characteristics and density; corrugated cardboard was largely used to represent brick blocks; toothpicks, wooden ice-cream sticks, wire were used as support structures for ventilated facade cladding.

Moreover, in floors, nails and steel wire represented the rebar and various types of tubes were used for the pipes of the underfloor heating system.

Fig. 2 – Wall and Floor System Model (Card n. 36 - Open Access Catalogue)



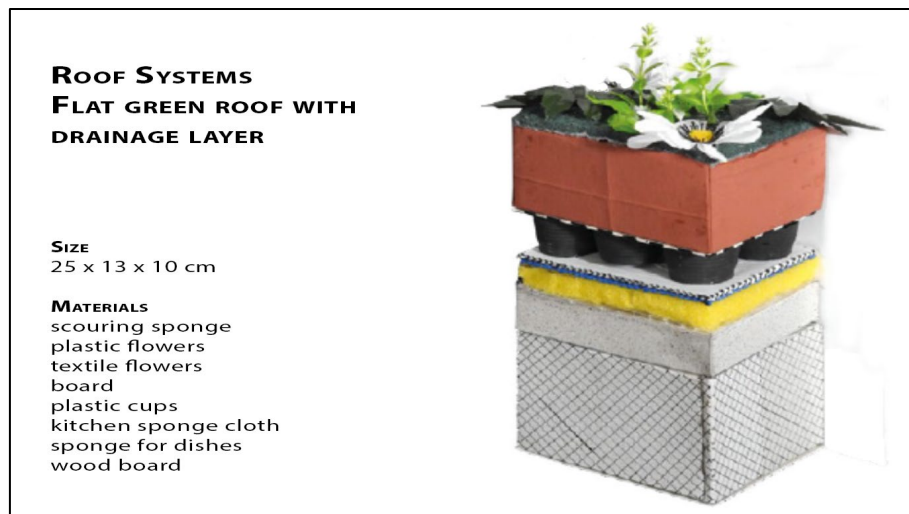
Source: Lacirignola and Montacchini, 2023

3.3 Roof systems

In the Roof Systems section, the green roof system was the favourite among the students.

For green roofs, students crafted the vegetation layer using dry leaves, stabilised moss, fabric, plastic or paper flowers and leaves. Dish sponges were a useful material for representing the different layers of the green roof technology package; sponges with an abrasive side were used to create the substrate and vegetation with a single material; egg cups, pill blisters, coffee capsules represented the drainage layer; surgical masks represented the filtration layer.

Fig.3 – Roof System Model (Card n. 79 - Open Access Catalogue)



Source: Lacirignola and Montacchini, 2023

4. Results and Conclusion

An exhibition was the first opportunity to present three-dimensional models of architectural details at the School of Architecture. Like the models, the exhibition itself was built at 'zero cost' using recycled materials and waste from previous installations.

Fig.4 – Detail models exhibition



Source: Own elaboration

Then, the presentation of the models in the form of an open-access catalogue [Lacirignola and Montacchini, 2023], made them available as a tool for studying and exploring the

technical elements of the building and highlighted how it is possible to use waste or recycled materials to make models and understand their function.

The catalogue is annually expanded with new models and holds an educational and training value for students. Within it they find the suggestion to adopt a working methodology based on the synergetic use of several forms of representation to understand objects and on hands-on experimentation to reinforce theoretical knowledge. Furthermore, it offers a collection that becomes a working tool for understanding the functional roles, layers and components that characterise the main parts of an energy-efficient building.

Thanks to its simple and accessible language, the catalogue serves not only as a learning tool, but also as an informative resource for anyone who wants to approach architectural technology and 'understand' how a building is made.

The experimental didactic activity described in the article, which refers to the learning-by-doing approach associated with the principles of the circular economy, proved useful and interesting and engaged students in understanding the fundamentals of architectural technology in a funny way.

This experience represents a step forward in architecture schools, where this approach is not so obvious and widespread and where students generally do not find many opportunities in the educational curriculum to challenge with in-field learning.

Overall, this is a methodology that can be replicated in other contexts, not only in architecture schools and not only in higher education, because it is able to combine learning, practical approach and even a little creativity. A way to bring the younger generation closer to the themes of circular economy and sustainability.

Acknowledgements

Thanks to all the students who supported us in this experimental didactic activity.

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

Fasano, C., Montacchini, E. & Tedesco, S. (2023). Circular economy experiential learning in a domestic lab. From coffee grounds to coffee boards. In *20 Architectural Experiences* (pp. 21-21). Editura Universitara Ion Mincu. <https://hdl.handle.net/11583/2983670>

- Lacirignola, A., & Montacchini, E. (2023). 100 MODELLI 3Di Di nodi tecnologici Di materiali di scarto Di studenti di architettura. <https://doi.org/10.57623/979-12-5953-090-5>
- Mayuk, S. G., & Coşgun, N. (2020). Learning by doing in architecture education: Building science course example. *International Journal of Education in Architecture and Design*, 1(1), 2-15.
- PaK, B., & De Smet, A. (2022). *Experiential Learning in Architectural Education, Design-build and Live Projects*, Routledge.
- Paris, S. (2017). Il rinnovamento della cultura tecnologica nel progetto, tra nuova tettonica e tecnologie digitali. Scenari internazionali dell'insegnamento e della ricerca. *Technè*, 13(13), 194-203. <https://hdl.handle.net/11573/1097315>
- Ulrich, K. T., & Eppinger, S. D. (2012). *Product design and development*. McGraw-hill.
- Yildirim, S. G., Baur, S. W., & LaBoube, R. A. (2014, September). Fundamentals of framing construction in architectural engineering; a hands-on learning experience. In *2014 Midwest Section Conference of the American Society for Engineering Education*, Sept (pp. 24-26).