

First International Conference on Sustainable Energy Education (SEED 2024)

Book of proceedings



SEED

sustainable energy education



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Valencia, Spain, 3 - 5 July 2024

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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

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

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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.

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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.

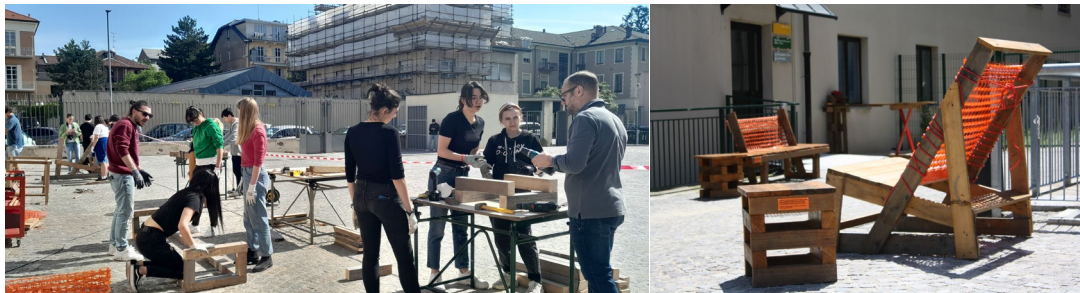
Fig. 1 – Human Powered Go-kart (students a.y. 2021/2022: C. Cavanna, I. Ciminiello, G. Dilauro, E. Ferrari, R. Giachi, S. Nardi)



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)

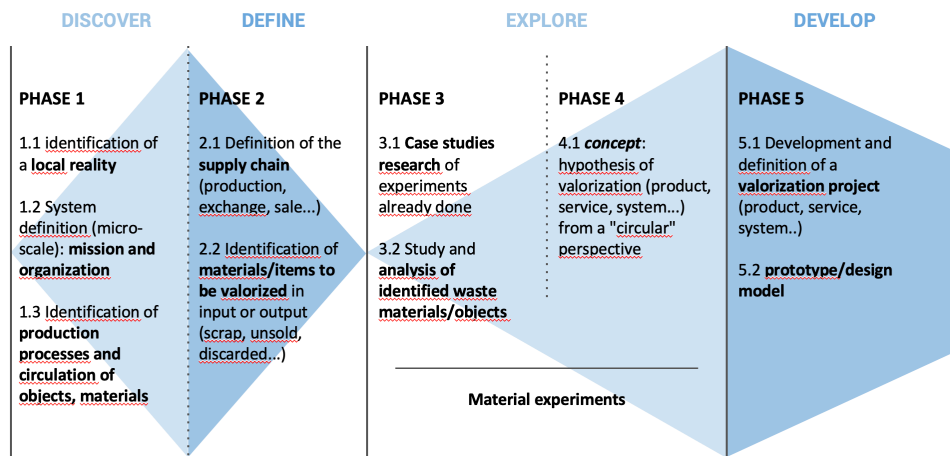
2.3 Circular economy scenarios for the real-world

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.

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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.