Education activities report

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Executive Summary

This deliverable (D6.2 “Education activities report”) presents how CIRC-UITS has translated its technical work on circular semiconductor and mass electronics value chains into a coherent, practice-oriented education strategy. Anchored in WP6 – Dissemination, Communication & Education, and specifically Task 6.3 – Education activities led by BeSu.Solutions, the report documents a portfolio of learning formats spanning the full skills pipeline: from schools and higher education to professional training and stakeholder engagement. The overarching objective is to make concepts such as circular value chains, digital twins, lifecycle sustainability and circularity assessment, and circular business models understandable, teachable and applicable for diverse target groups, thereby supporting the European Green Deal and Horizon Europe’s twin transition.

At the core of the strategy is a family of innovative, game- and workshop-based formats that make circularity challenges in electronics tangible and engaging. These include, among others, the browser-based game *Break Out!*, the conversational learning experience *Science.Gate*, the *Sustainable Startup Challenge*, the *CEBM Card Game*, the analogue *CE Estimation Game*, and ready-to-teach workshop concepts focused on circular business model innovation. All formats follow a didactic logic of experience–reflection–transfer and are closely linked to CIRC-UITS pilots and tools. Learners do not just receive theoretical information but work through realistic trade-offs between technical feasibility, environmental performance and economic viability. Their modular, print-and-play or browser-based design facilitates reuse, localisation and scaling beyond the project.

Complementing these innovations, CIRC-UITS has embedded project content into conventional education formats. Partners have integrated CIRC-UITS concepts, case studies and methods into lectures, seminars, project courses, school workshops, internal industry trainings and conference sessions. This dual approach – coupling new tools with familiar teaching structures – lowers the adoption barrier for educators, enables alignment with existing curricula and programmes, and ensures that results reach both pre-professional learners (pupils, students, trainees) and professionals able to implement change in organisations and value chains.

Some elements of the initial education plan were adapted rather than implemented in their original form. Instead of a single stand-alone behaviour-change app and large hackathon formats, the consortium prioritised a broader set of smaller, thematically focused tools and integrated open-innovation elements into game-based workshops and co-creation activities. Conversational and explanatory functions were embedded directly into specific learning experiences rather than into a generic project chatbot. These choices represent targeted optimisations: the resulting portfolio is closer to actual teaching and training practice, easier to maintain and update, and better positioned for integration into existing digital ecosystems and institutional structures. In this sense, the alternative achievements are more effective and impactful with respect to Horizon Europe’s emphasis on relevance, uptake and long-term exploitation.

Selected CIRC-UITS outputs are or will be made available as Open Educational Resources (OER) – for example, one downloadable teaching units, one print-and-play games, and twelve openly accessible videos and thirteen webinars via the project website referenced to YouTube and LinkedIn. Together with the activity overview and the general education plan, these resources create a reusable toolkit and reference model for future projects. Overall, the education activities of CIRC-UITS show how research on circular electronics and digitalisation can be systematically converted into robust, scalable and evidence-based learning formats that strengthen skills and capacities for the circular and digital transition in Europe.

List of acronyms

Acronym	Description
AI	Artificial Intelligence
APMS	International Conference on Advances in Production Management Systems
ATD	Association for Talent Development
CBM	Circular Business Model
CE	Circular Economy
CEBM	Circular Economy Business Model
CIRC-UITS	Circular Integration of ReUse and ReManufacturing Strategies in the Semiconductor Value Chain (Project Acronym)
CO_2e	Carbon dioxide equivalents
CSR	Corporate Social Responsibility
EC	European Commission
eLCA	Environmental Life Cycle Assessment
EU	European Union
GDPR	General Data Protection Regulation
HR	Human Resources
ICT	Information and Communication Technology
IPR	Intellectual Property Rights
ISAGA	International Simulation and Gaming Association
ITMC	International Technology Management Conference
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCS&CA	Lifecycle Sustainability and Circularity Assessment
L&D	Learning and Development
MCI	Material Circularity Indicator
MSE	Master of Science in Engineering
MoU	Memorandum of Understanding
OER	Open Educational Resources
PCB	Printed Circuit Board
PSS	Product–Service System
R&D	Research and Development
R-strategies	Framework of strategies for circularity (e.g., Refuse, Reduce, Reuse, Repair, ...)
SAGSAGA	Swiss Austrian German Simulation and Gaming Association
SDG	Sustainable Development Goal
SLCA	Social Life Cycle Assessment
SME	Small and Medium-sized Enterprise
SPOC	Single Point of Contact
ToT	Train-the-Trainer (Program or Approach)
UI	User Interface
UX	User Experience
WP	Work Package

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1. Introduction

1.1. Overview

This deliverable (D6.2 “Education activities report”) documents how CIRC-UITS has designed, implemented, and deployed its education activities to support the circular transformation of semiconductor and mass electronics value chains. It focuses on the educational dimension of WP6 – Dissemination, Communication & Education, and in particular on Task 6.3 – Education activities, led by BeSu.Solutions with contributions from all project partners. The report translates the project’s technical results into structured learning offerings along the full skills pipeline, ranging from school education and higher education to further education, professional training, and public outreach.

The overarching aim is to make complex topics such as reverse supply chains, digital product passports, lifecycle sustainability and circularity assessment, and circular business models understandable, teachable, and actionable for diverse target groups. To this end, CIRC-UITS pursues a dual strategy: on the one hand, it develops and pilots innovative, game-based and digital learning formats (e.g. serious games, simulations, conversational tools, ready-to-teach workshop concepts); on the other hand, it systematically integrates project content into conventional education formats (lectures, seminars, workshops, block courses, internal trainings, conferences). This combination of formats allows the project to reach a broad audience while ensuring that new tools can be embedded in existing curricula, training programmes, and organisational learning settings.

The report builds on the education plan defined in the Grant Agreement and refined throughout project implementation. It takes into account both the initially planned elements (e.g. development of a CE business simulation game, small serious games, chatbot, teaching materials, videos) and the consolidated set of actually implemented formats (including alternative or adapted solutions where necessary). Special emphasis is given to the pedagogical and communication principles underpinning all formats (science communication, game-based and situation-based learning, experience–reflection–transfer), the systematic target-group analysis, and the creation of Open Educational Resources (OER) that can be reused beyond the project.

By documenting the design rationales, the concrete formats, and the implemented activities, the deliverable provides an evidence base for assessing how CIRC-UITS contributes to capacity building for the European Green Deal and the twin transition. It also offers a reusable reference for future Horizon Europe projects and other initiatives that seek to couple technical innovation in circularity and digitalisation with robust, scalable education strategies.

1.2. Contribution to other Workpackages

The education activities described in this deliverable are closely interlinked with the scientific, technical, and exploitation work of CIRC-UITS. They both draw from and feed back into other work packages:

WP1 – Reference framework definition:

The CIRC-UITS reference framework, platform requirements, and pilot/scenario designs developed in WP1 provide the conceptual backbone for many educational formats. Core notions such as circular value chains, reference scenarios, validation targets, and KPIs inform the design of games, teaching units, and case-based

materials. Educational tools, in turn, help to communicate and test the WP1 concepts with different audiences, contributing to their refinement and internal/external understanding.

WP2 – Circular value chains digitalisation & data management:

WP2 delivers the data management strategy, platform for circular value chains, and digital twin prototypes. These elements are translated into learning content on data spaces, digital twins, AI-supported assessment, and secure data exchange. Educational formats (e.g. digital games, conversational tools) make these topics tangible for students and professionals, thereby increasing awareness and potential uptake of WP2 outcomes in future industrial and research contexts.

WP3 – Circularity & eco-design assessment:

Methods and services for Lifecycle Sustainability and Circularity Assessment (LCS&CA) and advisory models from WP3 form the methodological core of several learning tools, especially those dealing with environmental performance, trade-offs, and decision support. Education activities package these methods in accessible forms (e.g. in Science.Gate, in workshop and lecture material), enabling non-experts to understand and apply assessment logic, and thus supporting the broader objective of mainstreaming LCS&CA in industry and education.

WP4 – Technological implementation, validation & demonstration:

The industrial pilots and demonstrators developed and validated in WP4 provide real-world case studies and narratives for the educational formats. Games, estimation workshops, videos, and teaching materials all build on these pilots to create authentic learning scenarios. At the same time, educational workshops and game sessions act as low-risk “simulation rooms” where pilot-related ideas, challenges, and solutions can be tested and discussed with external stakeholders, supporting dissemination and validation.

WP5 – Exploitation, standardization & business modelling:

Insights from WP5 on circular business models, exploitation roadmaps, and standardisation are deliberately embedded in educational games and workshops that focus on business-model innovation and value-chain reconfiguration. In this way, education activities contribute to exploitation by familiarising future users, decision-makers, and multipliers with CIRC-UITS concepts and tools, and by creating a trained user base that can support commercial uptake and standardisation processes.

WP6 – Dissemination, Communication & Education:

Within WP6, Task 6.3 (education) is tightly coupled with Task 6.1 (dissemination) and Task 6.2 (communication). Education formats are disseminated via the project’s communication channels, and dissemination events often incorporate educational components (e.g. workshops using the developed games). The education plan thus strengthens the overall visibility and impact of WP6 by transforming passive information flows into active learning experiences.

WP7 – Project Management:

Project management (WP7) provides the governance, risk management, and coordination framework within which education activities are planned, implemented, and monitored. Feedback from education pilots and

activities also informs WP7's risk and progress assessments, especially regarding stakeholder engagement, uptake of project results, and alignment with the Description of Action.

Overall, the education activities documented in D6.2 act as a cross-cutting implementation layer that turns the methods, tools, and pilots of WP1–WP5 into competence-building instruments, thereby reinforcing the exploitation, standardisation, and long-term impact ambitions of CIRC-UITS.

2. Document Structure

This report is organised to move from strategic framing toward concrete formats, activities, and supporting resources:

- **Chapter 1 – Introduction:** Outlines the purpose, scope, and context of the education activities report and explains how education work in CIRC-UITS contributes to and benefits from other work packages.
- **Chapter 2 – Document Structure:** Provides a brief guide to the organisation of the deliverable and how the reader can navigate from the high-level education plan to specific formats, activities, and outputs.
- **Chapter 3 – Education Plan:** Presents the overall education strategy. Subchapter 3.1 introduces the general education plan, defining target groups, learning objectives, educational principles, and format types that are applicable beyond CIRC-UITS. Subchapter 3.2 details the CIRC-UITS-specific education plan, including objectives, mapping to technical WPs, key output families (games, teaching materials, digital tools, workshops, videos), and implementation/risk management considerations.
- **Chapter 4 – New Educational Formats:** Describes in depth the newly developed, innovative formats, with subsections on the underlying science communication and learning-theory basis, the didactic design principles, and the actual educational games and digital tools (e.g. Break Out!, Sustainable Startup Challenge, CEBM Card Game, CE Estimation Game, Science.Gate, and the “Meet the CE Heroes!” video series). For each format, the chapter outlines problem addressed, solution concept, target groups, learning objectives, mechanics, accessibility, and the science-communication layer.
- **Chapter 5 – Conventional Educational Formats:** Documents how CIRC-UITS’ results have been embedded in established teaching and training settings. It covers teaching materials, academic teaching at bachelor, master, and postgraduate levels, high-school activities, and further-education, internal training, and professional dissemination formats. This chapter demonstrates how innovative tools from Chapter 4 are complemented and scaled through conventional channels.
- **Chapter 6 – Educational Activities:** Aggregates all concrete education activities carried out during the project period in a comprehensive activity table. For each activity, it lists date, title, format, target group, relation to CIRC-UITS content, participant numbers, and responsible partner(s). This provides transparency on reach, uptake, and diversity of education actions.
- **Chapter 7 – Open Educational Resources (OER):** Summarises which materials are or will be made available as OER, including teaching units, games, videos, and webinars. It explains how these resources can be accessed (e.g. via the CIRC-UITS website or YouTube channel) and how they support reuse and adaptation beyond the project’s lifetime.
- **Chapter 8 – Conclusion:** Reflects on the overall achievements and strategic adaptations of the education work, including deviations from the original education plan where they occurred, and briefly argues why the achieved portfolio of formats and activities is highly effective in supporting the broader objectives of Horizon Europe.

This structure ensures that readers can either follow the full argument from strategy to implementation or selectively access the sections most relevant to their role (e.g. educators, technical partners, exploitation leads, policy stakeholders).

3. Education Plan

The education activities in CIRC-UITS are designed to translate the project's technical results on circular value chains for semiconductors into structured learning opportunities for different stakeholder groups. They complement and extend the dissemination and communication activities of WP6 by focusing specifically on competence development and skills acquisition.

The education plan builds on three main premises:

- education must cover the full pipeline from schools and higher education to professional training and life-long learning;
- formats must move beyond purely informational approaches and enable practice-oriented, experiential learning;
- activities must be technically robust and at the same time accessible for non-expert audiences, thereby supporting the broader objectives of the European Green Deal and the twin transition.

The following subsections describe first the general education plan as a conceptual and strategic framework, and then the concrete CIRC-UITS education plan that operationalises this framework in the project context.

3.1. General Education Plan

The general education plan provides an overarching framework that can be applied to CIRC-UITS and, in principle, to other projects addressing complex sustainability challenges. It is structured along four core dimensions: target groups, learning objectives, educational principles and types of formats.

Target groups:

The plan distinguishes three main groups along the skills pipeline:

- Pre-professional learners: pupils, apprentices, students and early-career trainees who are building foundational knowledge and attitudes towards circular economy, digitalisation and sustainable industry.
- Professional users: engineers, managers, consultants, production planners and other practitioners who require applied knowledge and decision support to implement circular strategies in real industrial contexts.
- Non-professional publics and broader stakeholders: citizens, policy makers, NGOs and other actors who influence or are affected by circular electronics but are not involved in technical implementation.

Each group is addressed with tailored depth and complexity, while key concepts (such as circular value chains, digital product passports and sustainability assessment) remain consistent across levels.

Learning objectives:

Across all groups, the general education plan pursues a set of recurring learning objectives:

- provide orientation on the challenges and opportunities of circular electronics and semiconductor value chains;
- foster systems thinking and understanding of how design, production, use and end-of-life stages interact;

- enable basic interpretation of sustainability and circularity indicators, including trade-offs between resource efficiency, environmental performance and economic viability;
- support practical competence in applying tools such as business model frameworks, assessment methods and digital platforms;
- stimulate reflexive and responsible decision-making in line with EU policy objectives (e.g. circular economy, climate targets).

Educational principles:

The design of all education activities follows these principles:

- Experience–reflection–transfer: learners should experience a situation (e.g. through a game or case), reflect on it with guidance, and then transfer insights to their own context.
- Alignment with real industrial practice: content is anchored in realistic pilots, case studies and data rather than purely abstract examples.
- Accessibility and transparency: methods, assumptions and limitations are explained in clear language so that non-experts can meaningfully engage with complex assessments and digital tools.
- Reusability and scalability: materials are developed in such a way that they can be reused, adapted and combined with local curricula or corporate training programmes.

Types of formats:

To operationalise these principles, the general education plan proposes a portfolio of complementary formats, including:

- serious games and simulations (analogue and digital) to explore circular strategies, value chains and design choices;
- ready-to-use teaching units (slides, worksheets, teacher guides) for schools and universities;
- digital tools such as chatbots and online platforms that allow self-directed exploration of project topics;
- workshops, webinars and hackathons that engage participants in co-creation and problem-solving;
- short, accessible media outputs (videos, quizzes, apps) to reach broader publics and motivate behavioural change.

This general framework ensures coherence across different activities while allowing adaptation to specific project contexts and partner capabilities.

3.2. CIRC-UITS Education Plan

The CIRC-UITS education plan applies the general framework to the specific context, objectives and work structure of the project. It is implemented mainly under WP6 – Dissemination, Communication & Education, and in particular Task 6.3 – Education activities, led by BeSu.Solutions with contributions from all partners. At the same time, it draws content and examples from all technical work packages (WP1–WP5).

Objectives and scope:

In line with the original Description of Action, the CIRC-UITS education plan aims to:

- communicate the basics of the project and circular electronics to young target groups and the general public;
- support university teaching and professional training through a dedicated circular economy business simulation game;

- create a set of small serious games and playful tools that can be used in science centres, schools and public events;
- provide ready-to-use teaching materials that teachers and trainers can directly integrate into existing curricula or training programmes;
- organise digital workshops, webinars and open innovation events (e.g. hackathons) to deepen engagement and generate additional ideas;
- develop digital companions (chatbot, app) that facilitate low-threshold exploration of project content and behavioural change in everyday life.

Mapping to project content

The education plan is closely integrated with the technical work packages:

- Results from WP1 (Reference framework) and WP3 (Circularity & eco-design assessment) provide the conceptual and methodological backbone for explaining circular value chains, sustainability indicators and advisory methods.
- Outputs from WP2 (Circular value chains digitalisation & data management) feed into educational content on data spaces, digital twins and AI-based assessment, and will be simplified and contextualised for different audiences.
- Pilots and demonstrators developed in WP4 (Technological implementation, validation & demonstration) supply concrete case studies and narratives for games, teaching units and videos.
- Insights from WP5 (Exploitation, standardization & business modelling) inform educational modules on circular business models, value creation logic and standardisation for circular electronics.

This systematic linkage ensures that education activities remain technically robust and reflect the state-of-the-art knowledge generated in the project.

Key educational outputs:

Under Task 6.3, the following main families of educational outputs are foreseen and have been or will be developed:

- a CE business simulation game designed specifically for university courses and professional training, illustrating how circular strategies, assessment tools and business models interact in decision-making;
- a portfolio of small serious games (e.g. board or card games, quiz formats) that address specific aspects such as R-strategies, product lifecycles or material criticality and are suitable for school settings, science events and informal learning;
- a project chatbot integrated into the CIRC-UITS web presence, enabling users to explore key concepts, project results and pilot stories in an interactive, conversational way;
- digital workshops and webinars on circular electronics, targeted at educators, students and practitioners, which make use of the project's games, tools and case materials;
- ready-to-use teaching materials for different age groups in general education schools (lesson plans, worksheets, teacher notes) and for higher education modules, aligned where possible with existing curricula;
- a series of short videos explaining core concepts, methods and pilot results in an accessible way;
- a behaviour-change app concept that encourages users in their everyday lives to adopt more circular practices related to electronics.

Implementation and risk management:

Implementation of the CIRC-UITS education plan follows an iterative, risk-aware approach aligned with the project's general risk management framework. Early prototyping and testing with selected schools, universities and professional users reduce the risk of low acceptance or misalignment with needs. Feedback from these pilots is used to refine content, didactics and level of complexity. Close coordination with dissemination (Task 6.1) and communication (Task 6.2) ensures consistency of messaging and efficient use of channels.

By the end of the project, the CIRC-UITS education plan will have produced a coherent set of tools, materials and formats that can be used beyond the project lifetime by partners and external stakeholders. In this way, the education activities contribute directly to the long-term exploitation and impact of CIRC-UITS, supporting capacity building for circular and sustainable value chains in the semiconductor and electronics sectors.

4. New Educational Formats

4.1. Methodology and Communication Theory: Science Communication as a Basis

Science communication is the systematic, audience-oriented translation of research for people beyond the expert community. It informs clearly, listens attentively, and invites participation. At its core, it explains methods, data, findings, and limitations in language that is accurate yet accessible, and it creates spaces for dialogue in which questions, concerns, and lived perspectives are taken seriously. This two-way exchange builds orientation—what is known, what is uncertain, and why it matters—while cultivating trust through transparency about evidence, assumptions, and the provisional nature of many results. When done well, science communication enables robust insights to reach decision-making in policy, administration, industry, education, and everyday life. It is also a feedback loop: societal responses reveal knowledge gaps, pressing problems, and practical constraints that can productively shape research agendas. A theory-informed approach is essential to keep these formats rigorous and meaningful. Clear objectives and well-defined audiences anchor every decision: which knowledge, attitudes, or behaviours should change, and for whom? Messages must be concise, jargon-light, and context-rich, explicitly stating what is established and what remains contested. Data are interpretable only with baselines, uncertainty ranges, and methodological notes; graphics, examples, and analogies should clarify rather than simplify away nuance. Accessibility is part of quality: legible design, alternative text, captioning, plain-language summaries, and multilingual options widen participation without diluting precision. Evaluation closes the loop—pre/post checks, reflective prompts, and transfer tasks verify whether learning persists and informs action. [4.1], [4.2], [4.3].

4.2. Methodology and Learning Theory

The learning landscape has changed markedly through modern, playful approaches. Game-based learning (GBL) and gamification integrate game mechanics and playful methods into the learning process to increase motivation, engagement, and long-term retention. A particularly valuable strand is situation-based gaming and learning, which employs realistic scenarios that confront learners with authentic challenges. These approaches are attractive because they make learning more engaging while advancing pedagogy and knowledge transfer.

Gamification and game-based learning mobilise intrinsic motivation by weaving rewards, points, and leaderboards into the learning journey. Used thoughtfully, these mechanics do more than entertain: they create clear goals, immediate feedback, and a tangible sense of progress. As a result, learning shifts from a perceived obligation to a purposeful challenge that invites effort, persistence, and curiosity [4.3], [4.5].

In situation-based and game-based formats, learners navigate realistic scenarios in which their choices carry visible consequences. This immediacy anchors abstract concepts in concrete action. Working through dynamic, sometimes ambiguous contexts, participants practise critical thinking and structured problem-solving under conditions that mirror real work. Knowledge is not merely transmitted; it is enacted, tested, and refined. Such designs cultivate active learning. Iterative decision cycles prompt learners to hypothesise, act, observe outcomes, and adjust strategies—closing the loop between understanding and application. Frequent, targeted feedback stabilises what is learned in long-term memory, while repetition across varied scenarios strengthens transfer to new situations.

When simulations emulate genuine processes—optimising a supply chain, allocating scarce resources, or orchestrating automation—participants experience the operational trade-offs and data constraints that shape practice. They leave not only with conceptual clarity, but with procedural fluency and a repertoire of strategies that survive outside the classroom.

Finally, gamification reliably amplifies collaboration. Playful yet purposeful environments require learners to negotiate roles, share information, and coordinate decisions. This social architecture builds psychological safety and collective efficacy—capabilities that matter especially for consultants and service providers, who must pair technical expertise with the ability to co-create solutions across disciplines and stakeholders [4.4], [4.5].

4.3. Designing Didactically Robust, Engaging Formats

When these principles of communication science meet methods of game-based learning, the results are didactically robust and genuinely engaging formats. These are sourced from credible studies and practice cases; roles, information sets, and constraints reflect the real systems in which decisions of players / learners unfold. Such formats are reinforcing links between evidence and outcome. Such formats invite participants to safe experimentation, errors become learning events rather than reputational risks—a powerful condition for professional growth [4.4], [4.5].

4.4. Creating a Bridge - Information, Education, Involvement

This fusion supports exchange across research, industry, and the broader public. Researchers contribute validated models and datasets; practitioners contribute operational realities, cost and quality constraints, and implementation know-how; citizens contribute values, equity concerns, and contextual knowledge of how policies land in everyday life. Joint sessions allow these perspectives to co-produce solutions, with simulations acting as a shared sandbox. Policymakers can “playtest” regulatory options before implementation; companies can explore circular-economy strategies or supply-chain adaptations; communities can evaluate the fairness and feasibility of interventions. Because the evidentiary spine is transparent, disagreements become tractable: participants can locate whether they diverge on facts, assumptions, or values.

The result is a coherent pipeline from evidence to experience to action. Science communication provides the structure and credibility that make complex topics graspable without distortion. Game-based learning supplies the experiential depth that turns grasp into capability. Together they create academically sound, accessible, and motivating formats that help diverse audiences make sense of complexity—and then do something constructive with it [4.1], [4.2].

4.5. Target Group Analysis, Empathy Maps and Application of the Methodology

In the CIRC-UITS project, we aim for the following target groups:

Dimension	Summary
Thinks	"I need to understand how complex systems (circular economy, sustainability) actually work and what trade-offs exist."
Feels	Curious, sometimes uncertain; motivated by visible progress and safe spaces to experiment.
Says	"Explain it simply." "Show examples." "Can I try it myself?"
Does	Attends courses/labs; uses simulations and case studies; explores what-if scenarios.
Pains	too much abstraction without context from use cases, few practice opportunities, fragmented materials.
Gains	Structured understanding, employable skills, confidence with complexity, theory-practice link.
Goals / Needs	Orientation, foundational concepts, feedback on decisions, visibility of system effects.

Tab. 1 Empathy mapping of stakeholder group: Pre-professional users (education pipeline)

Non-professional target groups—pupils and students, families, drivers and fleet users, local communities, hobbyists and repair-café participants, consumer advocates, and the general public—can also learn how the circular economy works and how to participate in it.

Dimension	Summary
Thinks	"How do we cut cost/risk, stay compliant, and unlock circular revenue streams?"
Feels	Outcome-driven, time-constrained; receptive to applicable, data-grounded content.
Says	"Make it actionable." "Show ROI and compliance impact." "Let's test it on our process."
Does	Runs workshops and shop-floor simulations; trials take-back/refurbishment flows; applies case-based methods
Pains	Silo-ed knowledge, implementation risk, unclear business case, one-off trainings without follow-through.
Gains	Operational insights, risk reduction, compliance readiness, shared understanding across teams.
Goals / Needs	Practical methods, decision support, metrics (cost/CO_2/quality), scalable training.

Tab. 2 Empathy mapping of stakeholder group: Professional users (workforce & leadership

When clear science communication is combined with game-based and simulation-inspired formats, complex research on circular strategies in automotive electronics (e.g., ECU remanufacturing, module-level battery reuse, PCB recycling) becomes graspable and motivating.

For professional audiences in automotive electronics—decision-makers, engineers, quality and logistics teams, after sales, as well as consultants—science communication combined with game-based learning turns circular economy into actionable practice. In realistic, risk-free simulations, participants prototype circular business models.

With circular economy as the core knowledge domain, these learning methods turn complex regulations, technologies, and value-chain dynamics into safe, evidence-based practice. Manufacturing decision-makers and consultants can prototype viable circular business models—from remanufacturing ECUs to second-life batteries—while professional users master the operational tactics that lift recovery rates, cut costs and CO_2, and keep electronics in service longer. At the same time, non-professional audiences—students, families, communities, and drivers—gain clear, motivating pathways to understand research, experience trade-offs through games and interactive media, and take part in returns, repairs, and responsible purchasing. Well-crafted science communication and engaging formats, such as educational videos, activate and sustain intrinsic motivation. In a sector racing toward electrification and software-defined vehicles, this integrated approach aligns profitability with sustainability and turns informed citizens into active contributors—before real money, materials, or trust are at risk.

Literature:

[4.1] Raessens, Joost: The Ludification of Culture. In: Mathias Fuchs, Sonia Fizek, Paolo Ruffino u.a. (Hg.): Rethinking Gamification. Lüneburg: meson press 2014, S. 91–114.

[4.2] Fizek, Sonia: Why Fun Matters: in Search of Emergent Playful Experiences. In: Mathias Fuchs, Sonia Fizek, Paolo Ruffino u.a. (Hg.): Rethinking Gamification. Lüneburg: meson press 2014, S. 273– 287.

[4.3] Strahringer, Susanne; Leyh, Christian (Hrsg.): Gamification und Serious Games: Grundlagen, Vorgehen und Anwendungen. Wiesbaden: Springer Vieweg 2017.

[4.4] Becker, Wolfgang; Metz, Maren (Hrsg.): Digitale Lernwelten – Serious Games und Gamification: Didaktik, Anwendungen und Erfahrungen in der Beruflichen Bildung. Wiesbaden: Springer VS 2022.

[4.5] Pürer, H. (2014). Publizistik- und Kommunikationswissenschaft. Ein Handbuch (2. Aufl.). UVK Verlagsgesellschaft mbH, Konstanz und München 2014.

4.6. CIRC-UITS' Educational Games

4.6.1. Game #1 "Break Out!"

Break Out! is a browser-based, 2D serious game that turns circular-economy theory into a vivid, playable experience. Learners step into narrative scenarios—such as repairing and redesigning an old-school car radio—and make consequential choices under realistic constraints. Immediate, transparent feedback shows how design decisions affect cost, quality, material flows, and CO_2. The result is a low-threshold, high-engagement entry point into systems thinking and sustainable action.

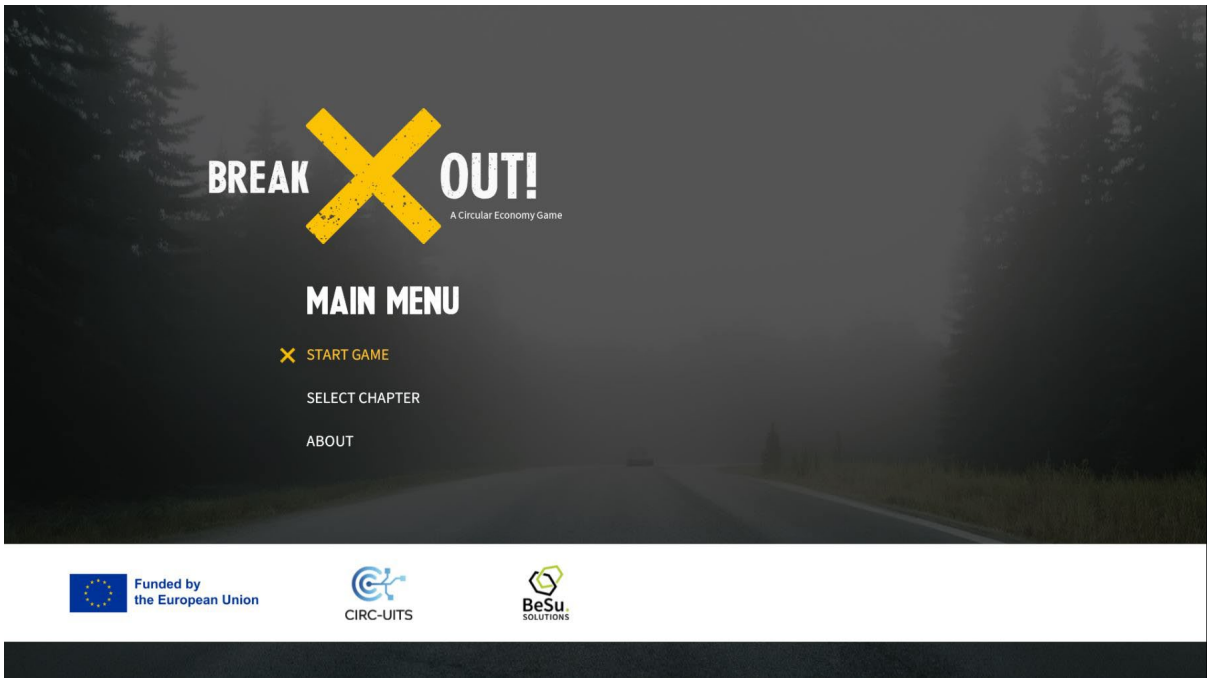

Fig. 1 Titel Screen of „Break Out!" an educational browser game, ver. 1.0.

Problem Addressed

Many learners find the circular economy abstract: R-strategies, recovery yields, and life-cycle trade-offs are difficult to grasp through text alone. Traditional materials lean on jargon and seldom provide safe opportunities to practise decision-making. *Break Out!* addresses this gap by embedding concepts in interactive stories that compress cause and effect and make complex systems tangible.

Solution Overview

The game blends point-and-click exploration with visual-novel storytelling and multiple solution paths. Players analyse components, choose between repair and replacement, select fasteners and materials, and experience the consequences of their choices. Built-in explainers present methods and uncertainties in plain language; a light achievement system nudges reflection and mastery. By design, the experience is short, focused, and repeatable—about twenty minutes per level—so it fits lessons, workshops, and outreach events.

Target Groups

Break Out! serves pre-professional learners in schools, vocational training, and universities; professional audiences in shopfloor and continuing-education settings; and non-professional publics, including families, community groups, and repair cafés. The content is tuned for accessibility and can anchor classroom work, museum programming, or public-engagement activities.

Learning Objectives

Learners develop systems literacy around resource cycles and R-strategies, the ability to analyse materials and recovery potentials, and the skill to make evidence-informed decisions under constraints. The game cultivates ecological judgement, strategic thinking, and prosocial competencies such as responsibility and cooperation, linking individual choices to measurable environmental and economic effects.

Mechanics and Experience Design

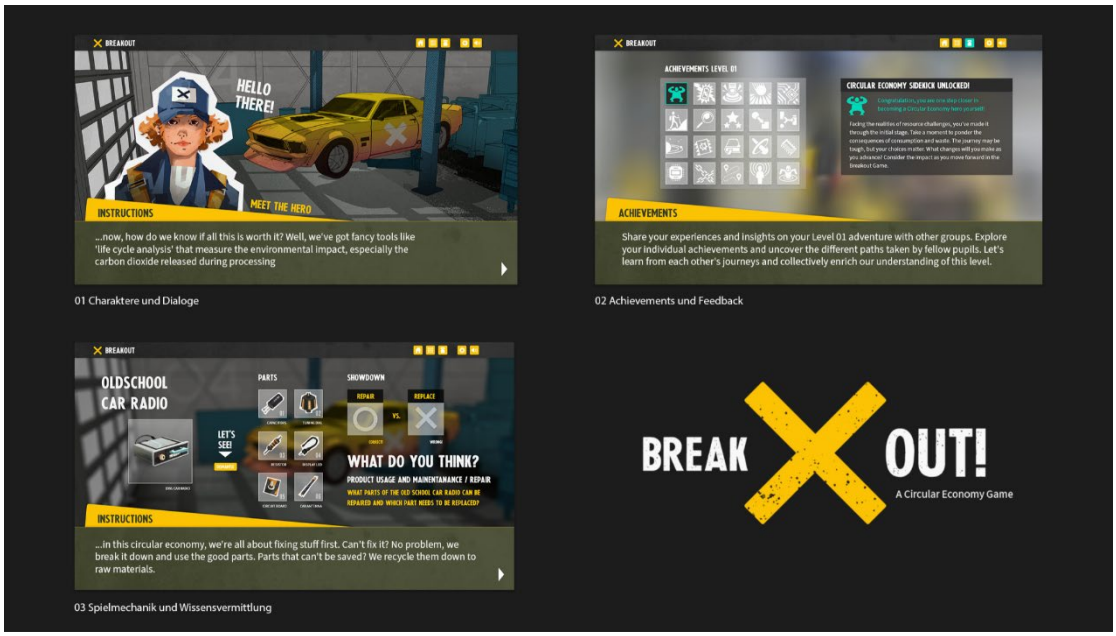

Fig. 2 Set of in game screens of „Break Out!" an educational browser game, ver. 1.0.

Each scenario asks players to weigh design and process options that carry visible consequences. A compact data layer tracks cost, CO_2, and material use, while short evidence cards clarify the assumptions behind the feedback. Humorous characters lower the threshold for engagement, and multiple "right" routes preserve agency without sacrificing rigour. Debriefs conclude each session so experience is connected back to concepts and forward to action.

Accessibility and Inclusion

The game runs in the browser, requires no prior knowledge, and uses a clear interface with readable typography and age-appropriate language. It can be deployed in formal and informal education and is prepared for barrier-reduced use through captions, alt-text, and straightforward navigation.

Pedagogy and Didactics

The instructional arc follows an experience-first model—play, debrief, apply. The design was developed with education experts and integrates storytelling, decision processes, and feedback systems that support deliberate practice. Transfer tasks prompt learners to map in-game reasoning to everyday decisions and school projects, ensuring that knowledge is enacted rather than merely received.

Science-Communication Layer

A concise science-communication spine structures the learning: concepts are introduced without jargon, uncertainties are made explicit, and sources are cited in brief "methods snapshots." Data-in-the-loop visuals show how small design shifts—such as moving from glue to clips—change disassembly time, recovery rates, and emissions. This transparency builds trust and helps learners judge claims beyond the game.

4.6.2. Game #2 "Sustainable Startup Challenge Card Game (11 R-Strategy Version)"

The *Sustainable Startup Challenge* is a facilitated, card-driven game that turns circular-economy principles into startup practice. Teams draft and test venture ideas by combining Challenge Cards with the 11 R-Strategy deck (Refuse, Rethink, Reduce, Redesign, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover). In short, focused rounds, players craft value propositions, choose circular strategies, and pitch mini business models while tracking impact and feasibility. The result is a fast, motivational path from concept to credible circular venture logic.

Fig. 3 Card-based education game „Sustainable Startup Challenge (*11 R-Strategy Version)”*, ver. 1.0.

Problem Addressed

Many companies and institutions want to “be sustainable” but lack a structured way to translate the circular economy into concrete business choices. Toolkits can feel abstract; workshops drift into green claims without evidence or economics. The game closes this gap by giving participants a shared language, a clear process, and evidence prompts that keep ideas honest and investment-ready.

Fig. 4 Card set of the „Sustainable Startup Challenge (*11 R-Strategy Version)”*, ver. 1.0.

Solution Overview

The game combines four decks: Rule Cards (how the game works), Task Cards, Method Cards, and the 11 R-Strategy Cards (Challenge Cards). Optional Heart- & Mindset Cards surface intrinsic motivation and ethical boundaries; Pitch Cards, Score Cards, and KPI/Point Trackers support evidence-based judging.

Target Groups

Designed for pre-professionals (schools, universities), professionals (intrapreneurs, accelerators), and public engagement (hackathons, community challenges). It works as a stand-alone ideation or as the front-end to deeper simulations. This game is considered competitive. You need at least two teams/groups to play the game.

Learning Objectives

Participants learn to frame opportunities through the circular economy lens, assemble a coherent circular business model with basic unit economics, articulate verifiable impact claims (CO_2e, waste, utilization, recovery yield), and pitch with clarity, avoiding greenwashing by linking every claim to a method or metric.

Mechanics and Experience Design

In the Sustainable Startup Challenge (11-R Edition), play runs in fast, repeatable loops designed to turn circular-economy principles into concrete startup choices. Each loop starts with teams selecting a challenge topic and, crucially, choosing one to three R-strategies they intend to apply—such as Repair, Reuse, Redesign, or Recycle. Guided by a compact set of task cards that mirror a lean business model, teams sketch the essentials: the problem and customer, a sharp value proposition, the solution outline, and the basics of channels, costs, revenues, and reverse-logistics needs. Method cards can be used at any moment to widen or focus ideas, but the loop keeps momentum: decisions must be made quickly and written down with at least two simple KPIs (for example, return rate, recovery yield, utilization, or CO_2e avoided per unit).

The loop then shifts from making to communicating. Each team delivers a short elevator pitch that connects its chosen R-strategies to the customer problem and the venture logic, stating the expected effects on cost, risk, and sustainability. Peers or a jury score the pitch on impact, feasibility, and clarity, and an anti-greenwashing check requires every claim to be tied to a metric and a method (claim + metric + method).

Accessibility and Inclusion

The game is a printed card game, requires no prior expertise, and uses clear typography, high-contrast layouts, and jargon-light phrasing. The result is a format that works equally well in classrooms, workshops, and public events—and is genuinely accessible to a wide audience.

Pedagogy and Didactics

The design follows experience → reflection → application. Task Cards mirror the lean-startup canvas, so ideas stay actionable; Method Cards inject divergent/convergent thinking; R-Cards anchor decisions in circular design logic. Debriefs prompt teams to link their choices to real constraints. The Sustainable Startup Challenge (11 R Edition) transforms circular-economy theory into a fast, collaborative startup lab. By fusing clear science communication with structured play, it helps diverse audiences design ventures where value grows with outcomes—not with throughput, and where impact claims are specific, measurable, and buildable.

Fig. 5 R-strategy cards of the „Sustainable Startup Challenge (*11 R-Strategy Version)*", ver. 1.0 by BeSu.Solutions

Science-Communication Layer

In the 11 R-Strategy Card Game, a clear science-communication spine keeps ideas rigorous without becoming technical. Each R-card explains the concept in plain language, names typical trade-offs, and points to short "methods snapshots". During pitches, teams must link every sustainability claim to a metric and a method—the built-in anti-greenwashing check turns slogans into transparent hypotheses. This traceability builds trust and helps players evaluate statements beyond the game session.

4.6.3. Game #3 "Circular Economy Business Models Game"

The *CEBM Card Game* is a facilitated, card-driven learning experience that invites younger audiences—especially students—to explore how circular economy business models (CEBMs) work in practice. Players assume one of three core roles inside a venture and collaborate to build sustainable models for different products and contexts. As teams negotiate trade-offs and choose strategies, they see how design, operations, and revenue choices affect cost, risk, utilization, and environmental impact. The result is a low-threshold, high-engagement on-ramp to systems thinking, teamwork, and innovation.

Fig. 6 „Circular Economy Business Model (CEBM) Game", ver. 1.0.

Problem Addressed

For many learners, "circular business model" remains abstract. Frameworks and reports often rely on jargon, while real-world decision points—what to design, who to partner with, how to earn revenue, what to measure—stay opaque. Traditional lessons rarely provide a safe space to test assumptions, compare options, and make consequences visible. The CEBM Card Game closes this gap by turning concepts into cooperative play, where choices are explicit, evidence is encouraged, and outcomes are easy to grasp.

Solution Overview

The CEBM Card Game is a serious, card-based learning system that translates circular-economy concepts into cooperative, hands-on modelling. It is delivered as an A6/A4 ready-to-print package (also suitable for digital use), fully available in German, and designed for use across school lessons, project weeks, and seminar settings. Players work within a shared "KREIS" (collaborative circle) to design and iterate circular business models for a given product, using rule cards, explainer handouts, task/hint cards, product cards, and adapted canvases for circular business models and partnerships. The material is purpose-built to make complex economic, social, and ecological interdependencies tangible through structured play.

Target Groups

Designed foremost for students and young adults in schools, and universities, the game also suits entry-level professionals, youth clubs, and public engagement (libraries, museums, community events). Its cooperative structure supports mixed-ability groups and cross-disciplinary classes. We chose German as the main language since we worked closely with German schools as evaluating test-participants.

Fig. 7 Digital tutorial of how setup the „Circular Economy Business Model (CEBM) Game", ver. 1.0.

Learning Objectives

Learners understand the building blocks of circular business models and how they differ from linear models, apply circular strategies to concrete products and services, link design and operational choices to basic unit economics and environmental outcomes, and practice collaboration, negotiation, and clear communication while avoiding greenwashing through evidence-seeking.

Mechanics and Experience Design

Play unfolds in a loop that mirrors circular value creation: teams first tackle tasks inside their own "company," then bring interim results into the KREIS for exchange, interface alignment, and transfer dialogue, before returning to refine responsibilities and pitch their business-model processes. A three-phase arc structures the experience—Preparation, Play, and Reflection & Transfer—with short, iterative cycles of doing, sharing, and improving. Roles are split across key system functions (e.g., production/remanufacturing and reconditioning, circular sourcing and industrial symbiosis; use phase with performance/access; and recovery via component/material/product recovery), so learners experience interdependencies rather than isolated tasks. Product cards (e.g., smartphones) anchor decisions in concrete lifecycles, while the Circular Business Model Canvas and Partnership Canvas make trade-offs, partner logic, and reverse-flow design explicit.

Accessibility and Inclusion

The game is plug-and-play for classrooms and workshops: print-ready formats, clear typography, and jargon-light instructions support mixed-ability groups and varied time budgets. Because the artefacts are modular (rule cards, explainer sheets, session handouts, canvases), facilitators can scale depth and pace.

The emphasis on guided prompts and visual structure lowers the barrier to entry for learners new to circularity and business modelling.

Pedagogy and Didactics

The didactic intent is explicit: to teach circular-economy concepts and closed product cycles by letting learners practise strategy under realistic constraints and data cues. Target groups include upper-secondary students and youth interested in sustainability and transformation; learning goals span systems literacy (value chains, data spaces), multi-stakeholder collaboration, and the ability to see opportunities and limits in circular transitions. The session design (Session 0–2) scaffolds from orientation to simulation to reflection, with explainer cards (e.g., circular business-model patterns, Business Model Canvas, Partnership Canvas) providing just-in-time theory that is immediately applied in the modelling tasks.

Science-Communication Layer

A built-in science-communication spine keeps the experience rigorous without overloading learners: explainer handouts introduce key terms in plain language, rule cards situate audience and learning goals, and canvases visualise relationships between actors and flows. Throughout, teams ground proposals in the language of circular strategies and recovery pathways, discuss constraints and uncertainties in the KREIS, and then consolidate evidence and assumptions on the canvases. The result is a transparent, method-aware process that helps learners articulate not only *what* their circular model does, but *why* it should work and *where* its boundaries lie—skills they can carry beyond the game.

4.6.4. Game #4 “Circular Economy Estimation Game”

The CE Estimation Game is an analogue, room-scale learning experience that makes circular-economy flows tangible and social. On the floor, ropes outline lifecycle loops (repair & maintenance, product/component/material reuse, energy recovery, “black hole”, etc.). Small sandbags represent 10% shares. Working in teams, participants estimate how real products—such as a washing machine, smartphone, and PV module—move through these loops. The act of placing sandbags sparks lively debate about design, behaviour, policy, and infrastructure, turning data into a shared, memorable experience.

Fig. 8 Workshop setup during a business event of EUREKA network

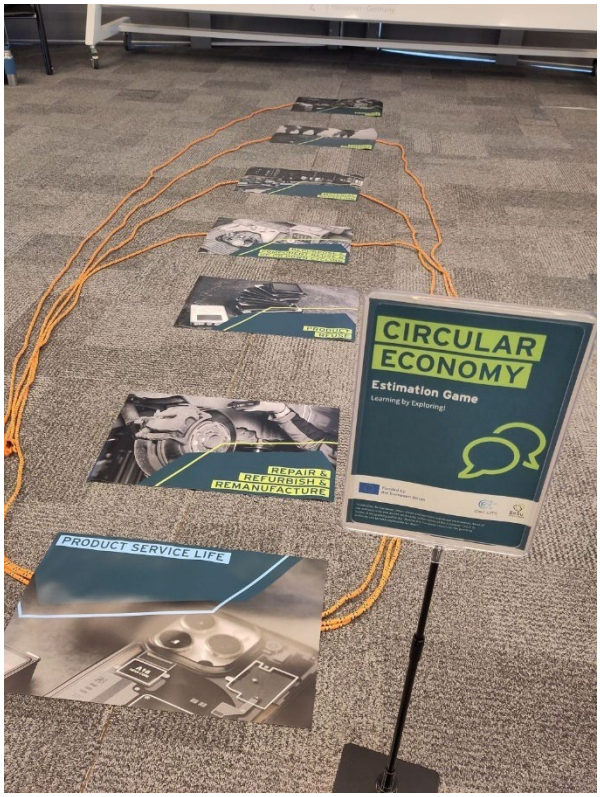

Fig. 9 Comet Cycles laid out the floor to create a 'step-in' effect for the participants.

Problem Addressed

Circular economy often remains abstract: percentages, loop names, and stakeholder roles can be hard to grasp without a felt sense of where products go. Conventional presentations rarely create a common, evidence-seeking conversation across users, manufacturers, recyclers, and policy makers. The CE Estimation Game closes this gap by staging circularity as a co-created estimation exercise followed by a structured dialogue, so misconceptions surface and collective insight emerge.

Solution Overview

The workshop uses a clear set-up: posters and factsheets for each product, a floor loop layout marked with ropes, team badges (User, Manufacturer, Recycler, Politician), and moderation cards with a step-by-step script. Each team receives large sandbags for its estimates; the facilitator keeps a set of small bags to reveal the reference distribution during the debrief. A compact pack of solution sheets visualises indicative mass-flow splits for each product, anchoring discussion in realistic ranges. Everything fits a portable, print-ready kit for quick deployment in classrooms, town halls, or conferences.

Target Groups

Designed for mixed audiences—students, practitioners, public officials, industry representatives, and citizens—the format works in schools, universities, corporate workshops, and community events. No prior circular-economy knowledge is required.

Learning Objectives

Participants learn to name key circular loops and distinguish product/component/material pathways, appreciate the different stakeholder perspectives and frictions, compare their mental models to evidence-based reference flows, and identify levers for improvement (design for repair, return systems, standards, incentives).

Fig. 10 Participants lively discuss and play the estimation game at the EUREKA networking event of the Hannover Fair 2025

Mechanics and Experience Design

A typical session follows a brisk estimate → compare → discuss loop. After a short warm-up, teams study a product factsheet and place sandbags into the floor loops to represent where *all units of that product* go

over their lifetime. Estimates are made product by product (e.g., washing machine → smartphone → PV module). The facilitator then reveals the reference split with smaller bags and invites quick reflections on gaps and surprises. The second act is a Fishbowl discussion (~45 min total, ~15 min per product) where the four stakeholder groups rotate into the inner circle to debate challenges and potentials from their vantage point—users (awareness, convenience, incentives), manufacturers (design & take-back), recyclers (process & economics), and politicians (standards, enforcement, incentives). A short wrap-up captures priority actions and data needs. Recommended timing: 60 min estimation + 45 min Fishbowl + 10 min wrap-up.

Accessibility and Inclusion

The game is low-tech and highly visual: large print, clear icons, and colour-coded loops support diverse ages and language levels. Instructions are written in simple language, and the facilitator script is modular, allowing shorter or longer runs. The materials are print-and-go; the floor layout can be scaled to any room. Because the core mechanic is physical and cooperative, it engages participants who might not speak up in traditional seminars.

Pedagogy and Didactics

The design follows experience → reflection → transfer. Estimation activates prior knowledge; the reveal confronts assumptions with reference data; the Fishbowl structures multi-stakeholder reasoning and connects insights to actionable levers (e.g., repairability standards, deposit/return, design for disassembly, consumer incentives). The closing prompts ask participants to name one policy, one design change, and one behaviour they would champion.

Science-Communication Layer

Factsheets and solution sheets present plain-language context (fleet size, service life, indicative flows) and make uncertainties explicit. The facilitator names what is known (e.g., mandated collection targets) and what varies by region or product generation, inviting local knowledge to refine the picture. Visual “data-in-the-room”—the sandbags on loops—turns abstract percentages into a shared object of discussion, building trust and transparency while teaching participants how to interrogate claims beyond the workshop.

4.6.5. Game #5 “Science.Gate – Meet Mara, your CE Bot”

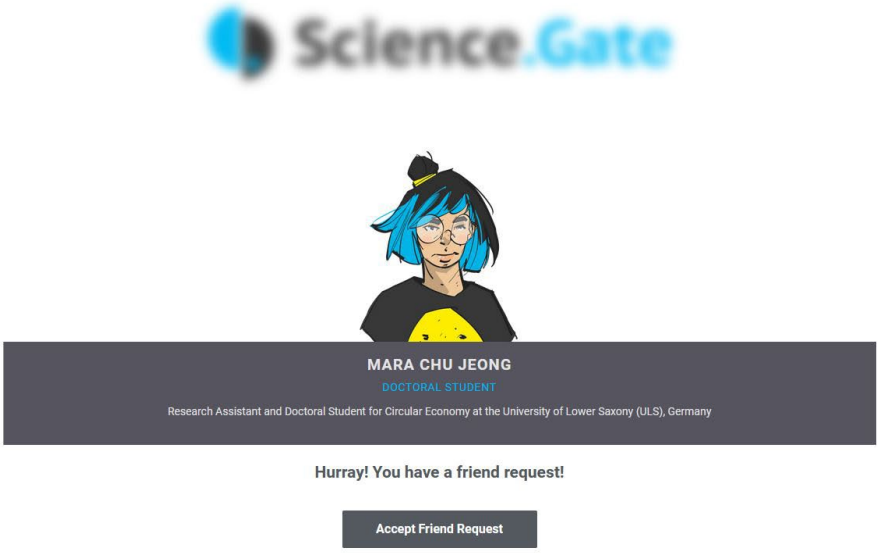

Fig. 11 Starting screen of the educational chatbot-based browser game “*Science.Gate*”, ver. 1.0.

Science.Gate is a guided, chat-based learning experience, browser-based, in which learners collaborate with Mara, a Circular Economy and Life Cycle Assessment mentor bot, to work through a realistic sustainability case. Instead of reading static PDFs, students investigate, decide, and justify their choices with Life Cycle Assessment (LCA) thinking. The storyline follows a consumer-goods company that wants to cut the footprint of coffee capsules; teams move from scoping the LCA to redesign options, end-of-life routes, and a decarbonisation pitch. The result is a low-threshold, high-structure path that turns circular economy concepts into applied practice.

Problem Addressed

Circularity and LCA often remain abstract in teaching: functional units, system boundaries, and contribution analyses are hard to internalise without hands-on modelling. In many courses, students receive a reading list but do not get a scaffolded workflow for turning evidence into design and business decisions. Science.Gate closes this gap with an interactive, playful chatbot, staged tasks and assignments, and ready-to-use deliverable templates, so learners practice *how* to do LCA-informed circular design—step by step, with accountability.

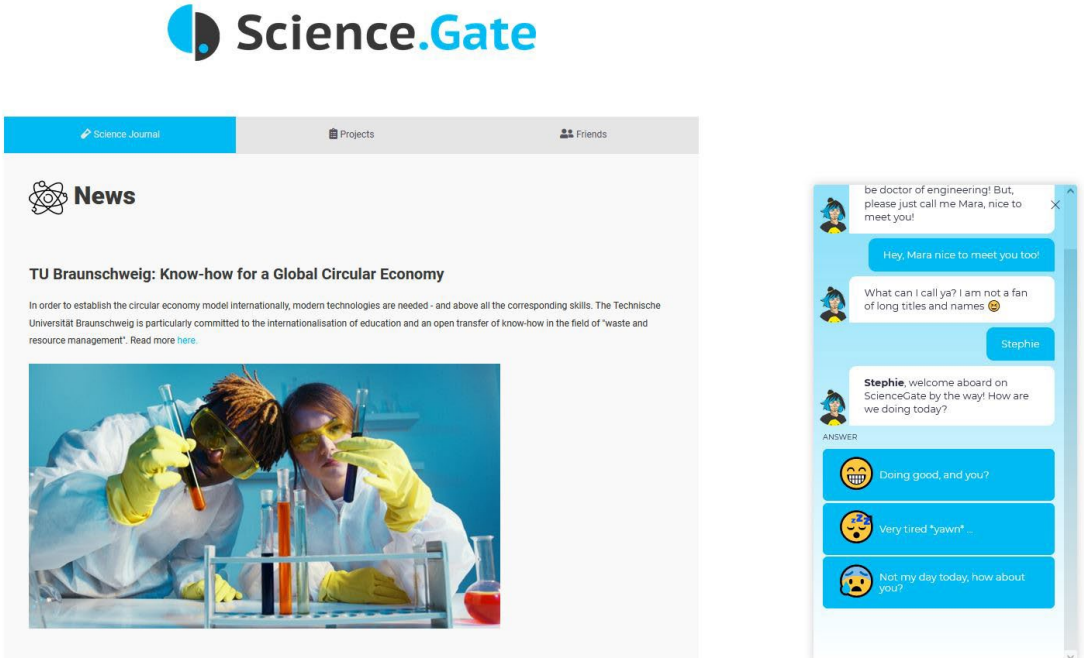

Fig. 12 In-game screen of the educational chatbot-based browser game "*Science.Gate*", ver. 1.0.

Solution Overview

Learners enter the fictional website and intranet Science.Gate and meet *Mara*, who introduces the project brief, milestones, and deliverables. A set of assignments structures the journey:

Task 1 – Read & Scope the LCA: Identify the functional unit, system boundaries, and carbon footprint of capsule coffee; relate impacts to design, production, distribution, and disposal.
Task 2 – End-of-Life Options: Compare current EoL pathways in Germany and evaluate alternatives (no treatment, landfill, incineration with energy, mechanical recycling with coffee contamination, mechanical/biological treatment with aluminium contamination). Summarise pros/cons and decarbonisation potential.
Task 3 – Design & Material Mitigation: Explore design changes and materials (primary/secondary aluminium, steel, fossil polymers, non-biodegradable and biodegradable biopolymers, spent-coffee materials). Judge technical, economic, ecological, and legal feasibility; estimate footprint effects using Mara's carbon-factor hints.
Task 4 – Department Strategy & Re-calculation: Propose a decarbonisation strategy from your department's viewpoint, recalculate the product footprint, and assess risk of problem shifting across departments.
Task 5 – Avoided-Use Alternatives: Consider options beyond capsules (mitigation by substitution). Curate the best ideas into your final pitch.

Mara keeps everyone on track with nudges, micro-explainers, and checklists. Students upload brief evidence notes (tables, charts, photos of measurements like full vs. empty capsule mass) and progressively assemble a pitch deck with a decision rationale and revised footprint.

Target Groups

This browser game is specifically designed for undergraduate and graduate courses in engineering, business, design, and environmental science; vocational programmes; boot camps for product managers and sustainability teams. Works equally well for intro LCA modules and circular product design studios.

Learning Objectives

Students learn to apply the core building blocks of Life-Cycle Assessment in a practical way. They define an appropriate functional unit, draw clear system boundaries, and use inventory and contribution analysis to understand where impacts arise and how those insights should steer design choices. Along the way, they compare circular strategies across design, materials, use, and end-of-life, weighing trade-offs and recognising the risk of problem shifting. Evidence gathered during the tasks is then translated into a department-specific decarbonisation strategy and a transparent re-calculation of the product footprint. Finally, learners synthesise their results in a concise stakeholder pitch that makes uncertainties explicit and sets out concrete next steps.

Mechanics and Experience Design

Science.Gate is structured as a research → decide → justify cycle. Each task begins with a short briefing and a focused action card that tells learners exactly what to do—define the functional unit, map end-of-life options, or score materials against criteria. As they progress, *Mara* unlocks micro-explainers that demystify concepts such as system boundaries, and offers factor hints that support back-of-the-envelope footprint estimates. Learners submit compact evidence—one chart, one paragraph—and see their progress through visual bars and green-check validations. At review gates, teams reconcile numbers, assumptions, and risks before moving on. The experience culminates in a 3–5-minute pitch that contrasts the baseline with the redesigned product, highlights the chosen decarbonisation levers, estimates CO_2 reduction, addresses residual risks, and proposes a 90-day action plan. Everything comes packed in a fun, relaxed and humorous package, to rise student's engagement and involvement.

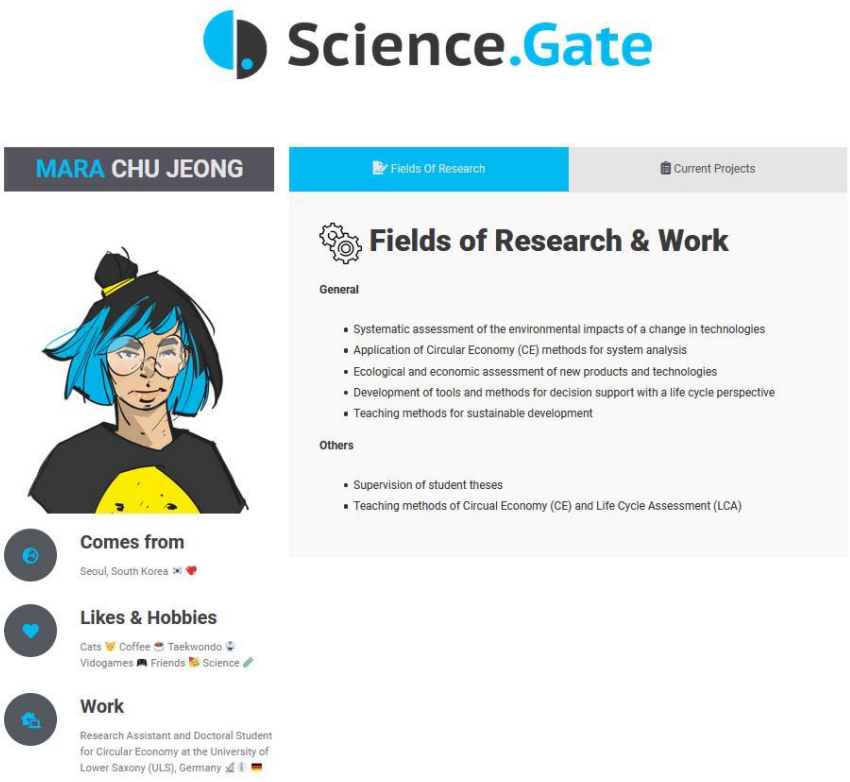

Fig. 13 Mara's profile within the educational chatbot-based browser game "*Science.Gate*", ver. 1.0.

Accessibility and Inclusion

Everything runs in the browser and is designed for clarity and ease of use. Prompts are written in plain language, micro-videos are captioned, and templates are intentionally compact to reduce cognitive load. Jargon appears only when necessary and is immediately illustrated with simple examples. The workflow adapts to different teaching formats—from a single, time-boxed seminar to multi-week projects—and all artefacts can be exported for straightforward submission in common LMS environments.

Pedagogy and Didactics

The learning design follows a guided-inquiry approach with just-in-time scaffolding. Tasks mirror an authentic project, but the scope remains tight so that students can focus on essentials without being overwhelmed. Learners alternate between evidence building (reading, quick measurements, comparative tables), decision-making (selecting strategies and documenting trade-offs), and communication (one-page summaries and a final pitch). Each step maps to an assessable deliverable—brief review notes, a pros/cons table, a feasibility matrix, a recalculated footprint, and a pitch deck—so progress is visible and grading is transparent.

Science-Communication Layer

Mara's guidance translates technical ideas into everyday terms and keeps the reasoning traceable. Questions such as "What exactly are we counting per cup?" ground the choice of functional unit, while prompts like "What enters or leaves our system?" clarify boundaries. Reference values are paired with uncertainty notes, and learners are asked to cite sources or mark assumptions explicitly. Where regional variation matters—collection rates, energy mixes—the bot requests local data and flags sensitivity. Visual checklists and simple factor cards make the data trail visible, helping students judge, defend, and responsibly transfer their claims beyond the exercise. In Tab. 3 all performed activities and outreach performance indicators are listed for all above listed formats developed in the project.

4.7. Educational Videos - "Meet the CE Heroes!" — Partner Video Series

Fig. 14 Take from one of the educational video series "*Meet the CE Heroes!*". video series of CIRC-UITS.

"Meet the CE Heroes!" is a short-form video series that spotlights each CIRC-UITS consortium partner and the disseminable results they have produced in the project. Every episode tells a crisp story of *what was built, why it matters, and how it advances circular economy practices* across the automotive and mass-electronics sectors. The tone is inspiring, informative, and accessible: no jargon, clear visuals, and concrete takeaways the public can grasp in under a few minutes.

Fig. 15 Link to CIRC-UITS YouTube-Channel hosting the educational video series and the 13 webinars on preliminary and final results if of CIRC-UITS.

Why it matters. The series turns technical project work into shareable impact narratives. Partners explain challenges and methods (e.g., design for recovery, data spaces, recycling routes), show prototypes or tools, and connect outcomes to real benefits—lower costs and risks, higher recovery rates, better compliance, and reduced CO_2. The goal is to grow understanding and trust in circular solutions while giving credit to the teams doing the work.

Audiences and channels are international and non-academic audiences—from students to professionals curious about technology, sustainability, and mobility. Episodes are optimized for LinkedIn, X (Twitter), Instagram, YouTube, and the project website, with subtitles and simple language for maximum reach.

Fig. 16 Take from BOSCH's educational video series "*Meet the CE Heroes!*". video series of CIRC-UITS.

5. Conventional Educational Formats

The CIRC-UITS consortium not only developed new and innovative educational formats, as described in Chapter 4, but also systematically embedded project results into established and widely used teaching and training formats. These conventional formats—lectures, seminars, block courses, master classes, workshops, conference talks, and internal training sessions—ensured that knowledge on circular value chains for semiconductors, digital product passports, life cycle sustainability assessment (LCSA), and circular business models was disseminated directly into existing educational pipelines and professional communities.

As documented in Tab. 3, CIRC-UITS partners used conventional education formats at multiple levels: bachelor and master programmes, postgraduate and executive education, school-level outreach, and industry-facing events and internal trainings. In doing so, the project reached a broad audience, ranging from school pupils and university students to engineers, managers, and policy stakeholders, and anchored CIRC-UITS case studies in curricula and sectoral discourse.

The following subsections provide a concise overview of the teaching materials produced (Section 5.1), academic teaching activities that employed CIRC-UITS findings and case studies (Section 5.2), school-level teaching activities (Section 5.3), and further education, internal training, and professional dissemination via conventional formats (Section 5.4).

5.1. Teaching materials

Across the project duration, a substantial body of conventional teaching materials was developed to support lectures, seminars, workshops, and conference presentations that drew on CIRC-UITS content. These materials include:

- Slide decks and lecture notes explaining the project concept, pilots, and results (e.g. LCSA studies, circularity metrics, digital toolbox, and digital product passport approaches).
- Case-study descriptions and short narratives that present CIRC-UITS pilots (e.g. circular PCB design and manufacturing, disassembly and sorting advances, recycling routes, and reverse supply-chain concepts) as concrete examples for discussion in university courses and professional trainings.
- Seminar handouts and assignment prompts for bachelor, master, and postgraduate courses, where students were asked to analyse CIRC-UITS pilots, reflect on circular value chains, and connect project findings to broader themes of sustainable manufacturing, circular business models, and net-zero transitions.
- Presentation materials for conferences, industrial workshops, and internal trainings, which contextualised CIRC-UITS within the European policy landscape, critical raw materials discussions, and industry roadmaps.

These materials are designed to be modular and reusable: lecturers and trainers can adopt individual slides, case summaries, or assignments and integrate them into existing course structures. In many cases, CIRC-UITS materials serve as “exemplary cases” that make abstract concepts such as LCSA, circularity metrics, or

digital traceability tangible for learners. Where appropriate, the same content is also used to prepare audiences for the more innovative and game-based formats described in Chapter 4, ensuring that conventional and new formats are didactically aligned.

5.2. Academic teaching involving CIRC-UITS' findings and case study

CIRC-UITS results were systematically integrated into conventional academic teaching across several partner universities and higher-education institutions. These activities comprise standard lectures, recurring seminar sessions, and intensive block courses at bachelor, master, and postgraduate levels.

At bachelor level, CIRC-UITS was introduced as a central case study in courses on sustainable manufacturing, industrial engineering, and environmental engineering. For example, extra-course seminars and lectures within management and environmental engineering programmes used CIRC-UITS to illustrate how circular economy principles can be operationalised along the electronics and automotive value chain. Project pilots and the associated digital toolbox were presented as concrete examples of how digitalisation supports recycling, remanufacturing, and design for circularity. In some cases, this content was embedded in established courses on "Management of Industrial Plants", "Sustainable Production and Supply Chain", or similar modules, reaching cohorts of several dozen to several hundred students per edition.

At master level, conventional lectures and seminar-style sessions introduced CIRC-UITS as a reference project in courses on integrated sustainable management of production systems, solid waste management and treatment, and specialized modules on circular production. These sessions typically followed a classic academic structure: a lecture segment presenting key concepts and empirical results (e.g. LCSA outcomes, circularity metrics, process innovations), followed by guided discussion and, in some cases, short group assignments using the CIRC-UITS pilots as case material. In several master programs and graduate schools (e.g. international masters on sustainable management, sustainable challenges, and sector-specific net-zero transitions), CIRC-UITS was explicitly framed as an exemplary case of circular and net-zero transition in the mobility and manufacturing sectors.

Postgraduate and executive education formats further extended this reach. Lectures in specialised master programmes and graduate schools introduced CIRC-UITS to participants from multiple European countries and diverse professional backgrounds, using a classical lecture + Q&A format. Here, CIRC-UITS served both as a technical case (semiconductor and PCB value chains, reverse logistics, and recycling technologies) and as an organisational example of cross-sector collaboration, European standardisation efforts, and digital innovation for circularity.

Taken together, these conventional academic formats reached well over one thousand students and early-career professionals during the project period. They ensured that CIRC-UITS results are embedded in current curricula and can have a lasting impact on how future engineers, managers, and sustainability experts understand and implement circular economy strategies in electronics and mobility.

5.3. High school teaching involving CIRC-UITS' findings and case study

While the main focus of CIRC-UITS' educational work lies in higher education and professional training, partners also engaged with school-level audiences through conventional teaching elements. These activities typically combined short, age-appropriate lectures, demonstrations, and experiments with discussions on resource use, recycling, and circularity in electronics.

In outreach activities with primary and secondary pupils, partners used accessible lecture formats to introduce basic concepts such as critical raw materials, the environmental impacts of mining and extraction, and the challenges and limits of recycling electronic products. Everyday examples (e.g. jewellery, smartphones, game consoles) were employed to bridge the gap between abstract resource flows and pupils lived experiences. Simple experiments and classroom demonstrations—using analogue methods such as sieving, density separation, or airflow separation—were embedded in a conventional "frontal teaching plus experiment" structure and used to illustrate why separation and high-quality recycling are technically demanding.

At upper-secondary level (high schools), CIRC-UITS content was introduced via teacher-led workshops and project days that followed familiar formats: introductory presentation, structured activity phase, and plenary reflection. Even where game- and workshop-based tools were employed (described in more detail in Chapter 4), the surrounding lesson design remained conventional, with clear learning objectives, curriculum linkage, and teacher moderation. This ensured that CIRC-UITS-related activities could be integrated into existing school timetables and subject structures (e.g. physics, geography, economics, or technology classes) without requiring structural changes.

Overall, these school-level engagements contributed to raising awareness of circular electronics among younger audiences and provided teachers with concrete examples and narrative material that can be reused in future classes.

5.4. Further education, internal training, and professional dissemination

Beyond formal education at schools and universities, CIRC-UITS partners used conventional further-education and dissemination formats to reach industrial practitioners, standardisation experts, policymakers, and other stakeholders. These activities include conference presentations, workshops, seminars, and in-company trainings documented in Tab. 3.

At the professional and industry level, partners contributed to conferences, summits, and specialised workshops in areas such as automotive materials, electronics manufacturing, wire and cable technologies, e-mobility, and sustainable mining and mineral supply. In these events, CIRC-UITS was presented through standard conference formats: plenary and parallel-session talks, seminar-style presentations, and panel discussions. Typical contributions introduced the European context (e.g. regulatory expectations, critical raw materials, circularity targets), outlined CIRC-UITS pilots and technical advances (e.g. direct metallisation, innovative PCB design, digital tools), and discussed implications for cost, CO_2 emissions, reliability, and processability in industrial practice.

In addition, several events explicitly targeted mixed expert audiences from academia, industry, and public administration, often in the form of half-day conferences, thematic seminars, or transfer workshops. Here, CIRC-UITS served as a unifying case for discussing digital product passports, data spaces, and the integration of reverse supply chains. Conventional formats such as keynotes, thematic sessions, and moderated roundtables were employed to facilitate exchange and to position project results in ongoing sectoral and policy debates.

Internal and in-company trainings, formed another important pillar of conventional education activities. For example, dedicated on-site workshops were organized to build competencies on circular economy principles, reverse supply chains, and sustainable manufacturing practices among employees of industrial

partners. These sessions followed a classic training structure: introductory lecture on key concepts and project insights, presentation of relevant CIRC-UITS pilots, and moderated discussion of how to translate these ideas into the company's own processes and investment decisions. Such internal trainings are crucial for moving from awareness to concrete organizational change and for ensuring that project results are taken up beyond the research context.

Finally, CIRC-UITS results were communicated to broader professional and semi-professional communities through talks and seminar-style events at universities, makerspaces, and regional innovation fora. These activities typically combined a conventional lecture format with time for questions, networking, and informal exchange. In all cases, the use of familiar structures (presentation, Q&A, panel, workshop) lowered the threshold for participation and made it easier to integrate CIRC-UITS content into established event series and institutional programmes.

In summary, conventional educational formats played a complementary role to the innovative, game-based and digital learning tools developed in CIRC-UITS. They ensured that project results were anchored in existing educational and professional ecosystems, reached large and diverse audiences, and could be taken up and replicated with minimal additional resources.

6. Educational Activities

This chapter provides an overview of all educational activities carried out within CIRC-UITS during the project period and documents how the educational strategy described in Chapters 3–5 has been implemented in practice. While the previous chapters focus on the design rationales and format types (new educational formats, conventional academic and professional formats), this chapter aggregates the concrete activities across partners, countries, target groups, and delivery channels.

The core of the chapter is Tab. 3, which lists all single and recurring educational activities related to CIRC-UITS. For each activity, the table records the date (and, where applicable, recurrence), title, format (e.g. lecture, seminar, workshop, master class, conference contribution, game-based session), primary target group, a brief description of how the content connects to CIRC-UITS pilots and findings, the number of participants, and the responsible partner(s). Together, these entries make visible how CIRC-UITS results have been deployed along the full education and skills pipeline—from schools and universities to professional and industry-facing trainings—and provide a transparent basis for assessing the project's educational reach, uptake, and potential for continuation beyond the project duration.

Tab. 3 List of all single or recurring educational activities within the project's period

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
From 19/09/2023 to 20/09/2023	**Activity Title:** E MOBILITY WORKSHOP 2023. New technology trends in automotive materials development. **Summary:** Presentation of the European Scenario referred to the strong expectation for sustainable development and to the stringent regulations on the full life cycle of the products with impacts over automotive sector. Presentation troughs Pilot 1,2 and 3 for new sustainable PCB design and fabrication. **Format**: Workshop **Target Groups**: Engineers and designers from Tier 1 and OEMs in the electronic industries.	50	CRF
Since November 2023 (Public via web domain)	**Activity Title:** "Science.Gate – Meet Mara, your CE Bot" — A Conversational Learning Experience for Circular Economy **Summary:** Science.Gate is a browser-based, chat-driven learning experience where learners work with Mara, a Circular Economy & LCA mentor bot, to solve a realistic sustainability case. Instead of reading static PDFs, students investigate, decide, and justify choices using Life-Cycle Assessment thinking—from defining the functional unit to comparing redesigns and end-of-life routes. The storyline centers on reducing the footprint of coffee capsules, culminating in a concise decarbonization pitch. The result is a low-threshold, high-structured pathway that turns circular-economy concepts into applied practice. **Format:** Browser-based conversational learning tool (web app); guided tasks, micro-explainers, and pitch deliverables; suitable for seminars, studios, and workshops.	26 weeks × 37 participants = 962 clicks per semester	BESU

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	Target Groups: Undergraduate and graduate courses in engineering, business, design, environmental science; bootcamps for product managers and sustainability teams; also usable in public/guest lectures and seminars (public-domain deployment). Proven in academic settings (e.g., an BeSu accompanied seminar at TU Braunschweig with 37 participants, weekly use across one semester). After that, it became more widely known, so we estimate the number to be around 35 participants per seminar per semester, with at least one visit to the website per week since then.		
30.05.2024	**Activity Title**: "Think circular, act together" — Transfer Workshop: *How does a Circular Economy work?* (CE Estimation Game + Fishbowl) **Summary:** A fast, hands-on transfer workshop that brings together experts from science and industry within the Lower Saxony Center for Research on Work in the Circular Economy (KREIS). Participants use the Circular Estimation Game to map real product flows and then enter a moderated Fishbowl to compare four perspectives—legislation, consumers, electronic-device producers, waste/recycling operators—turning data and debate into clear next steps. Hosted under the event theme "Think circular, act together," the session makes circularity tangible, social, and decision-oriented in under two hours. **Format:** Facilitated workshop kit and room-scale analogue game (floor loops + sandbags) with moderated Fishbowl discussion; print-and-go materials (posters/factsheets), badges, solution sheets; on-site delivery at KREIS events. **Target Groups:** Mixed expert audiences from academia and industry, policy and public administration, recycling and waste-management firms, and producer representatives (electronics/automotive); also suitable for advanced students	~80 participants	BESU
17.06.2024	**Workshop Title: "**There's no end to a circle." A workshop on how to address circularity challenges in electronics	33	TNO
13.06.2024	**Activity Title:** 2024 EMEA Regional Wire and Cable Summit. New technology trends in automotive materials development. **Summary:** Presentation of the European Critical Raw Material topic, focused on this impact on automotive electrification and its needs, in particular on Cu and other elements usable on electronics systems. Show potential different solution born in CIRCUITS Project specifically on the development of sustainable design and methods able to reduce CO2 emissions and facilitate reusing in PCBA supply chain, based on a circular model to produce new high added value components.	50	CRF

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	Format: Seminar **Target Groups**: Engineers and designers from Tier 1 and OEMs in the electronic industries.		
10.07.2024	**Activity Title:** 11th International Conference on Sustainable Development in the minerals industry. **Summary (Hook):** Sustainable Supply of Critical Raw Materials. Show how CRM are used in electronics parts and how eliminating one from the materials flowchart may influence the availability. Show potential different solution born in CIRCUITS Project specifically on the development of sustainable design and methods able to reduce CO2 emissions and facilitate reusing in PCBA supply chain, based on a circular model to produce new high added value components, in according to Stellantis Materials Roadmap. **Format**: Conference **Target Groups**: Engineers and designers from Tier 1 and OEMs in the electronic industries	100	CRF
Since 2024 (Public web domain)	**Activity Title:** "Break Out!" — An Interactive 2D Serious Game on Circular Economy **Summary:** Break Out! is a browser-based, 2D serious game that turns circular-economy ideas into a vivid, playable experience. Learners step into narrative scenarios—e.g., repairing and redesigning an old-school car radio—and make real trade-offs under realistic constraints. Immediate feedback shows how design choices shift cost, quality, material flows, and CO_2, creating a low-threshold, high-engagement entry point into systems thinking and sustainable action. **Format:** Browser game (runs on standard devices; ~15–20 min per scenario); captions/alt-text-ready; clear UI and jargon-light prompts. *Indicative usage (reasonable estimates):* ~450–600 sessions per 16-week semester with ~30 learners (≈1 session/week), or ~120–200 plays in a 2-day workshop (5–8 teams × 3–5 rounds). **Target Groups:** Pre-professional learners in schools, universities; professional audiences in shopfloor and continuing-education contexts; and the general public (families, community groups, repair cafés). Suitable for classroom use, museum programming, and public-engagement events.	~450–600 sessions per 16-week semester with ~30 learners	BESU
13.09.2024 11.09.2025	**Activity Title**: SUPSI block module: Sustainable products and process: technology and business **Summary:** students are introduced on the industrial sustainability and circularity topics and are involved in the development of innovative projects with companies under the perspective of sustainable and circular products. Results from CIRC-UITS are presented especially concerning	15 students per edition	POLIMI, SUPSI, ERION

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	the LCSA assessments performed on the project pilots that are used as examples; the disassembly and sorting advancement realised by ERION and PoliMi. **Format:** a one-week optional bachelor course co-organized by SUPSI and HE-ARC de Neuchâtel. **Target Groups:** University students from multiple fields (engineering and economics).		
From September 2024 to September 2025	**Activity Title:** Different Lectures in the SUPSI Bachelor of Industrial Engineering. Involved courses: Sustainable Production and Supply Chian; Industrial Sustainability: Methods and tools. **Summary:** The results of the CIRC-UITS project have been illustrated during several lectures, especially focusing on: LCSA; circularity metrics; circular economy principles. The results have been used as examples of innovative technologies, methodologies and tools to drive the sustainability and circularity way to produce. **Format:** University Lectures. **Target Groups:** bachelor students.	From 15 to 30 per edition	SUPSI
September-December 2024 September-December 2025	**Activity Title:** Different Lectures in the SUPS Master of Science in Engineering (MSE). Involved course: Integrated Sustainable Management of Production System. **Summary:** The results of the CIRC-UITS project have been illustrated during several lectures, especially focusing on: LCSA; circularity metrics; circular economy principles. The results have been used as examples of innovative technologies, methodologies and tools to drive the sustainability and circularity way to produce. **Format**: University Lectures. **Target Groups**: Mater students.	40	SUPSI
15.10.2024	**Activity Title**: Circular economy in organizations **Summary:** Organized within the CircThread and Circ-Uits projects, the event explores key topics such as the adoption of sustainable materials, the role of standardization, decision-making tools for sustainability, and practical applications of circularity in both public and private organizations. A roundtable on circular economy implementation featuring representatives from Circular Lugano, GUESS, PLASTEX, the City of Lugano, and the Politecnico di Milano that presented the CIRC-UITS project concept and results. **Format**: a seminar and roundtable with Swiss companies' representatives in order to present some best practices under the perspective of the adoption of circular approaches. **Target Groups:** Swiss industrial companies' representative from multiple sectors.	30 industrial representatives	POLIMI, SUPSI

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	Note: This activity was also listed as a dissemination activity in the dissemination report, as it serves both purposes		
25.10.2024 & 21.10.2025	**Activity Title:** "Seminario su Manifattura Sostenibile ed Economia Circolare" (in English: Seminar about Sustainable Manufacturing and Circular Economy). **Summary:** An extra-course seminar held for the BSc students of Management Engineering from Politecnico di Milano, in the course of "Gestione degli Impianti Industriali" (in English: Management of Industrial Plants). In the seminar, the CIRC-UITS project was presented as a significant example showcasing the potential and the applicability of circular economy practices. The objectives of the project and its pilots were illustrated, and CIRC-UITS was used as an example to show how digital innovation can enable circular practices. **Format**: Seminar at the university. The seminar has been recurrent since 2024. **Target Groups:** BSc Students	2024 Edition: almost 200 students 2025 Edition: almost 400 students	POLIMI
22.11.2024 / 23.05.2025 / 14.11.2025	**Activity** Title: Closing the Loop of Critical Materials **Summary:** A board Game to be used to the better understanding of the meaning: "Critical Materials". Players need to from teams and the challenge is to manufacture products that are critical. Due to events some materials become unavailable, and the companies need to find recycling solutions or need to cooperate with junk yards. **Target Groups**: High school students or University Bachelor students.	12-16	OFFIS
28.11.2024	**Activity Title:** The challenges of electronics manufacturing. Sustainability, policies, and strategies: managing investments to remain competitive. **Summary:** Innovation and sustainability from an OEM's perspective Presentation. Shown Stellantis Materials Roadmap with a focus also on electronics materials new trend because PCBA are usually considered a black box during parts design, but with an important impact on GWP (global warning potential). Show potential different solution born in CIRCUITS Project specifically on the development of sustainable design and methods able to reduce CO2 emissions and facilitate reusing in PCBA supply chain, based on a circular model to produce new high added value components. **Format**: Workshop **Target Groups**: Engineers and designers from Tier 1 and OEMs in the electronic industries.	50	ALPHA/CRF
20.03.2025	**Activity Title:** International Master in Sustainable Management & Corporate Social Responsibility	20 students	POLIMI

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	Format: a lecture with post-graduate students where POLIMI presented some relevant examples of how digital solutions can support the adoption of circular approaches into manufacturing companies **Target Groups:** Post-graduate students from multiple engineering disciplines		
First quarter 2025	**Activity Title:** "CBM Now!" — Business Simulation Trials with the CEBM Card Game (TU Braunschweig) **Summary:** A cross-disciplinary simulation where university students use the CEBM Card Game to design new circular business models in a realistic network setting. Mixed teams (engineering, business, design, sustainability) assume complementary roles across the value chain and co-create models that connect design choices, operations, partners, revenues, and reverse logistics. By iterating under time pressure and pitching evidence-backed ideas, students see how circular strategies translate into viable offerings and measurable impact—turning theory into actionable, circular venture concepts. **Format:** Facilitated print-and-play workshop kit (A6/A4 decks + Circular BM/Partnership canvases); 90–150-minute session with short brief → 2–3 modeling loops → mini-pitches → debrief. Optional rubric for impact, feasibility, clarity, and an anti-greenwashing check (claim → metric → method). **Target Groups:** University students from multiple fields (engineering, industrial design, business, environmental sciences), early-career researchers, and entrepreneurship clubs. Works in courses, hackathon, and incubator bootcamps	72 students total	BESU
02.04.2025	**Activity Title:** "WEEE in the Loop" — Participative Workshop at the Global Innovation Summit 2025 (EUREKA, HANNOVER MESSE) **Summary:** At the Global Innovation Summit 2025 within the Circular Value Creation Forum, participants co-created insights on circular electronics using the Circular Estimation Game and a moderated Fishbowl. Experts and interested attendees mapped real WEEE flows (e.g., smartphones, washing machines, ECUs) and debated solutions from four viewpoints—legislator, consumer, producer, recycler—to translate data and debate into clear takeaways. The session's purpose was to surface needs and requirements for the next EUREKA call roadmap, turning hands-on estimation and dialogue into actionable input. **Format:** On-site, facilitated workshop kit + room-scale analogue Circular Estimation Game (floor loops & sandbags) followed by a structured Fishbowl discussion; 45–60 minutes total with intro, estimation, debate, and wrap-up.	~18 participants	BESU

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	Target Groups: Mixed audience from industry (SMEs/large companies), research & universities, public authorities/policymakers, sector associations, plus interested members of the public attending the EUREKA-organized forum at HANNOVER MESSE (international participants).		
07.04.2025	**Activity Title:** SUSPERTZE DIGITALA: DIGITAL PRODUCT PASSPORT: TRANSPARENCY AND TRACEABILITY FOR THE INDUSTRY OF THE FUTURE CONFERENCE **Summary:** Within the framework of the Suspertze Digitala program, which aims to promote digital transformation in SMEs, and in collaboration with the Regional Development Agencies of Bizkaia, a day was organized on the Digital Product Passport. **Target Groups**: Mixed expert audiences from academia and industry	N/A	INNOVALIA
14.05.2025	**Activity Title:** "Forging Circular Economy & Tomorrow's Future" — EU CIRCUITS Showcase at TU Braunschweig **Summary:** A month-long, on-campus science-communication series presenting EU-CIRCUITS results in a hands-on, jargon-light format. Visitors explored circularity through mini-talks, live demos, and playable prototypes. Each showcase gathered ≈55 participants, turning complex CE concepts into clear takeaways and sparking dialogue on how universities and industry can accelerate circular innovation. **Format:** On-site showcase series (pop-up stations + 5–10-minute micro-talks + guided demos/play sessions ≈55 participants per showcase across multiple show days within the month. **Target Groups:** TU students (engineering, business, design), early-career researchers and staff, local school groups, and interested public visitors from the Braunschweig region. Delivery in German/English to match a mixed academic and community audience.	~55 participants per showcase	BESU
15.05.2025	**Activity Title:** Data in Action (BAIDATA's event) **Summary:** European projects such as CIRC-UITS and CIRPASS are driving the development of the Digital Product Passport (DPP), highlighting its role as a key enabler of greater circularity, transparency, and sustainability across industries. During this event, the usefulness and relevance of the DPP were clearly demonstrated. **Target Groups**: Mixed expert audiences from academia and industry (BAIDATA's members)	N/A	INNOVALIA
03.06.2025	**Activity Title:** EIPC summer conference in Edinburgh. The case of CIRCUITS project.	40	ALPHA

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	Summary: Presentation for the European PCB fabrication community focusing on the added value of the work done in CIRCUITS, specifically on the direct metallization and on IME (Pilot1 & Pilot3) but also including digital (e.g. GRETA) **Format**:Seminar **Target Groups**: PCB fabricators and their suppliers		
16.06.2025	**Activity Title:** "Raising the awareness for sustainable product design with CIRC-UITS´ innovative digital tools and serious games" / "Serious games to inspire circular thinking" — EU Green Week Partner Event at OFFIS (Oldenburg) **Summary:** Planned as part of EU Green Week, this on-site workshop at OFFIS, Oldenburg set out to raise awareness for sustainable product design using CIRC-UITS' digital tools and serious games. Under the umbrella event "Raising the awareness for sustainable product design with CIRC-UITS' innovative digital tools and serious games," participants were invited to explore circularity through short talks and hands-on gameplay—connecting green product design, right-to-repair, and critical materials with accessible formats for schools and the wider public. Though the session did not run due to low registrations, the announcement copies and materials were published on web and social channels. **Format:** Physical workshop kit and mini-talks (OFFIS venue), featuring serious games and interactive tools; print-ready agendas/teasers plus slide deck for facilitation. **Target Groups:** Primarily school pupils (Grades 11–12/13) and the general public, with additional relevance for teachers and local stakeholders interested in circular practices and sustainable product design; German-language delivery aligned to the OFFIS/Oldenburg pilot context.	~135 students	OFFIS & BESU
18.06.2025	**Activity Title:** Lecture in the first-level Post-graduate Master "Skills4Transition" delivered by POLIMI Graduate School of Management. Course Title "Net Zero Challenges for Transportation Sector". **Summary:** The CIRC-UITS project was illustrated on the last day of the course as an exemplary case of Net Zero and Circular Economy transition in the mobility sector. The project was illustrated in detail, and its innovativeness impact was underlined. **Format**: Online lecture **Target Groups**: first-level post-graduate master students from Bulgaria, Czechia, Germany, Italy, Romania, and Slovakia.	40 Students	POLIMI

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
Since July 2025 (Public web domain for download)	**Activity Title:** "CEBM Card Game" — An Interactive Card Game on Circular Economy Business Models **Summary:** The CEBM Card Game is a facilitated, card-driven experience that helps learners explore how circular economy business models work in practice. Players take on three core roles inside a venture and collaboratively design sustainable models for different products and contexts. As teams weigh trade-offs and choose strategies, they see how design, operations, and revenue choices affect cost, risk, utilization, and environmental impact. The result is a low-threshold, high-engagement on-ramp to systems thinking, teamwork, and innovation. **Format:** Print-ready A6/A4 workshop kit (download, print, cut); modular decks (rule cards, explainer sheets, task cards, product cards, canvases); clear typography and jargon-light prompts; plug-and-play for classrooms and workshops. (Downloadable from the BeSu website for DIY print & play.) The project website is now publicly accessible, and the full print-and-play kit is ready for download and distribution to schools, workshops, and community events. **Target Groups:** Primarily students and young adults in schools and universities; also suitable for entry-level professionals, youth clubs, and public engagement settings (libraries, museums, community events). Cooperative structure supports mixed-ability and cross-disciplinary groups. German is the main language (aligned with school pilots); other languages feasible via the print-ready template. A German secondary school in Lower Saxony was accompanied as the pilot cohort for this game.	Approx. 60 participants. (4 classes × ~15 students per class = ~60 students accompanied)	BESU
11.09.2025	**Activity Title:** Sustainable products and process: technology and business **Format:** a one-week workshop co-organized by SUPSI and Université de Neuchâtel where students were involved in the development of innovative ideas under the perspective of sustainable products **Target Groups:** University students from multiple fields (engineering and economics).	30 students	POLIMI, SUPSI
24.09.2025	**Activity Title:** "Sustainable Startup Challenge "– Student Hackathon (11 R-Strategy Edition) **Summary:** A one-day, private student-organized hackathon where participants used the Sustainable Startup Challenge Card Game (11 R Edition) to turn circular-economy principles into startup ideas. In fast loops, mixed-discipline teams combined Challenge Cards with R-Strategies (e.g., Repair, Reuse, Redesign, Recycle) to craft value propositions, sketch lean business models, and pitch evidence-backed concepts. The format keeps momentum	18 students total	BESU

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	high, links every claim to a simple metric (return rate, recovery yield, CO_2 avoided), and turns enthusiasm into credible circular venture logic. **Format:** Day-long, facilitated workshop/hackathon using the printed card game (Rule, Task, Method & 11 R-Strategy decks); schedule = kickoff & team formation → 2–3 design sprints (ideate/model/test) → elevator pitches with scoring on impact, feasibility, clarity and an anti-greenwashing check (claim + metric + method). Setup: ~18 students, 4–5 teams, 6–7 hours incl. breaks; projector/whiteboards; optional mentor check-ins and jury panel. **Target Groups:** University students across disciplines (engineering, business, design, environmental studies)		
16.10.2025	**Activity Title:** "Education on AI enabled Fault Detection" **Summary:** How can AI be used for Fault Detection. Showcase of the ECU Fault Detection with AI from OFFIS in collaboration with Bosch. **Format:** Workshop **Target Groups:** Manufacturer in Lower Saxony	3	OFFIS
16.10.2025	**Activity Title:** Recycling lecture and performance of experiments for primary school pupils. **Summary:** Accessible recycling lecture for primary school pupils (age 8 to 9 years old) on the importance and how-abouts of recycling, sustainability and circularity. Starting from shining minerals in jewelry, the step was made to the use of minerals and metals in modern consumers goods such as cars, mobile phones, game devices, etc. It was shown what it takes to mine and extract metals from the earth and how recycling can play a role in reducing the environmental impact and scarcity of resources. Based on the example of making hot chocolate in the class room (and everybody drinking it), the pupils had to come up with a solution if this could be separated back into milk, chocolate powder and sugar, illustrating the difficulties and limits in recycling their electronic toys, phones, tv's and game consoles. With simple materials, the pupils carried out their own recycling experiments, trying to separate different materials from each other by using screen, air, density etc. Reduction of consumption and their own role in this was highlighted. **Format**: Interactive lecture and experiments **Target Groups**: Primary school pupils (being the future of sustainability).	2 x 24 pupils	MARAS
21.10.2025	**Activity Title:** SMTA International conference in Rosemont USA. Enabling Assembly Reliability and Extending Processability While Significantly Lowering CO_2 Footprint and Energy Consumption Using Low Temperature Solder **Summary:** Presentation of the paper written by ALPHA &	60	ALPHA

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	STELLANTIS on the reliability of low temperature solder connections and its impact on reducing the carbon footprint of electronics manufacturing and its viability for automotive interiors. **Format**: Seminar **Target Groups**: Engineers and designers from Tier 1 and OEMs in the electronic industries		
10.11.2025	**Activity Title:** "Fix, Reuse, Redesign: Circular Economy for Makers" — Talk for Makerspaces in Braunschweig **Summary:** A hands-on talk that brings circular economy to the workbench. Using relatable examples and the 11 R-strategies, attendees learn how design-for-repair, smart fasteners, and reverse flows turn waste into value. Short live demos and glimpses into our learning tools (Break Out!, CEBM Card Game, CE Estimation Game) show how small design choices change cost, uptime, and CO_2—so makers leave with concrete moves they can apply in their next build. **Format**: Keynote-style slides and Q&A; demo items; print-&-play resources. **Target Groups:** Makers, repair cafés, students & apprentices, local startups and tech enthusiasts in the Braunschweig region; accessible language (DE), suitable for mixed technical backgrounds.	24 participants	BESU
11.11.2025	**Activity Title:** International Master in Sustainable Challenges & Mega Trends **Format:** a lecture with post-graduate students where POLIMI presented some relevant examples of how digital solutions can support the adoption of circular approaches into manufacturing companies **Target Groups:** Post-graduate students from multiple engineering disciplines.	30 students	POLIMI
Fourth quarter of 2025	**Activity Title:** Seminar-style lecture held as part of the "Solid Waste Management and Treatment" at Environmental Engineering course, Politecnico di Milano. **Summary:** During the seminar, the CIRC-UITS project was presented as a key case study highlighting the potential and practical application of circular economy principles. In particular, pilot 4 and the developed digital toolbox were illustrated, showing how CIRC-UITS leverages digital innovation to enable and optimize recycling processes. **Format**: Seminar at the university. **Target Groups:** MS Students	60 Students	ERION
29.11.2025	**Activity Title:** Internal Training on Circular Economy and Sustainable Practices **Summary:** Pollini organized an internal training session to raise awareness and build competencies on circular	50	POLLINI

Date of first activity / and recurring	Activity Title / Target Group / Short Description of content relation to CIRC-UITS	Numbers of Participants	Responsible Partner(s)
	economy principles and sustainable manufacturing practices. The session introduced key concepts from the CIRC-UITS project, including reverse supply chains and strategies for reusing industrially relevant semiconductors. Employees explored how these principles can be applied in Pollini's operations to reduce waste, improve resource efficiency, and align with EU sustainability goals. In addition, practical examples and case studies from the project were discussed to illustrate real-world applications. **Format:** On-site workshop with presentation and discussion **Target Groups:** Pollini employees (production and quality teams)		

7. Open Educational Resources

Open educational resources (OER) are defined as educational materials that are freely available for use, adaptation, and redistribution. These licences, which are frequently Creative Commons licences, grant users the "5 Rs": The following principles should be observed: Retain, Revise, Remix, Reuse and Redistribute. Open Educational Resources (OER) are defined by their dual quality as both freely accessible and openly licensed. This characteristic is pivotal in delineating their nature, as it signifies that the original creator has explicitly authorised the utilisation and adaptation of these materials by third parties.

Common OER Licenses (Creative Commons):

- CC BY (Attribution): The utilisation of this medium is permitted for a wide range of applications, including commercial endeavours, with the stipulation that the original creator is duly acknowledged.
- The CC BY-SA (Attribution-ShareAlike) license is employed. The provision for remixing and reuse is permitted, however, any new work must be shared under the same license or a compatible license.
- CC BY-NC (Attribution-NonCommercial): Permission is granted for utilisation and adaptation, though not for commercial exploitation.
- CC BY-ND (Attribution-NonDerivatives): The utilisation of the material is permitted; however, the creation of derivative works is prohibited.
- CC0 (Public Domain): The work is released into the public domain, with no restrictions on its usage.

7.1. Educational Material planned to be published as open educational resources

Tab. 4 List of planned open educational resources

Name of Educational Material	Licence
Information Technology and IT Applications (NA 043)	CC BY-ND
Nonferrous Metals (NA 066)	CC BY-ND
Principles of Environmental Protection (NA 172)	CC BY-ND
Road Vehicles and Mobility (NA 052)	CC BY-ND
Digital platforms (DIG)	CC BY-ND

7.2. OERs accessible via Circ-Uits website or YouTube channel

The YouTube channel of CIRC-UITS hosts any open access learning videos and dissemination videos.

Tab. 5 List of open access learning videos on YouTube channel

Name of Educational Material	Licence
EU-CIRCUITS • Episode 01 | Results from BeSu.Solutions GmbH	CC BY-ND
EU-CIRCUITS • Episode 02 | Results from BOSCH	CC BY-ND
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8. Conclusion

The education work in CIRC-UITS has largely realised – and in several respects strategically reframed – the ambitions set out in the original work plan for WP6. Building on the initial concept to "communicate the basics of the project to young target groups and the general public" and to support upskilling along the full education pipeline, the consortium has delivered a coherent portfolio of game-based, workshop-based and conventional teaching formats that make circular value chains in electronics accessible, tangible and actionable for a wide range of audiences.

A central achievement is the development of a family of serious games and interactive formats (e.g. browser-based games, analogue card and estimation games, startup challenges and ready-to-teach workshop concepts) that translate complex topics such as circular business models, R-strategies, lifecycle thinking and reverse supply chains into experiential learning situations. These formats closely follow the CIRC-UITS pilots and technical tools and therefore provide not only engaging experiences, but also a realistic view of circularity challenges in industrial semiconductor and electronics contexts. Their modular, print-and-play or browser-based design makes them easy to adopt, reuse and scale across institutions and countries, directly contributing to Horizon Europe's objective of widening skills and knowledge diffusion for the green and digital transitions.

In parallel, the project has anchored its results in conventional education and training activities at schools, universities and in professional development programmes. Lectures, seminars, block courses, workshops and webinars have been updated to include CIRC-UITS concepts, methods and case material. This dual approach – combining innovative formats with established teaching structures – has proven highly effective: it lowers the barrier for educators to adopt new content, allows the games and tools to be embedded in existing curricula and programmes, and ensures that the project's outputs reach both early-stage learners and professionals in positions to implement change in organisations and value chains.

Not all elements of the initial education plan were implemented in the exact formats originally envisaged. For example, instead of investing heavily in a single, standalone behaviour-change app or in large-scale hackathon formats, the consortium prioritised the development and validation of multiple smaller, thematically focused tools and learning units, and integrated "open innovation" elements into game-based workshops and co-creation sessions with educators and practitioners. Similarly, rather than building a generic project chatbot detached from concrete learning settings, conversational and explanatory functions were embedded directly into specific learning experiences and digital tools. These adaptations proved advantageous: the resulting outputs are more closely aligned with real teaching and training contexts, easier to maintain beyond the project, and better suited for integration into existing digital ecosystems used by universities, companies and intermediaries.

Overall, the achieved results arguably offer a higher impact than the originally more technology-heavy concepts would have provided. By focusing on robust, reusable and context-rich educational tools that are tightly coupled to the project's technical results, CIRC-UITS delivers exactly what Horizon Europe seeks to foster: evidence-based, practice-oriented learning formats that support the European Green Deal, strengthen skills for the twin transition, and can be picked up and further exploited by a broad community of educators, trainers and stakeholders after the project's end.