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Living Labs as tools and places for RbD in Sustainability: transformative education in Architecture

Living Labs como herramientas y lugares para la RbD en Sostenibilidad: educación transformadora en Arquitectura

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Abstract

Living labs play a major role as instruments allowing the introduction of new pedagogical approaches in the education of architecture students through designing, building and operating experimental sustainable housing prototypes. In recent years an important development of educational and research oriented living labs in higher education has been linked to the Solar Decathlon Europe (SDE) Competition, an international competition of universities for designing, building and operating energy self-sufficient solar houses. One of these prototypes provides, under direction of the author, a transformative learning experience to local and international students since 2012 focusing on the topics of sustainable housing, energy and lifestyle. Results of educational research on its methodologies and impact confirm the positive contribution in the field of transformative sustainability education.

Keywords: transformative learning, living labs, sustainability education, build-learn approach, decarbonization.

Thematic areas: spaces for learning, cooperative learning (CA), design/build, blended teaching and flipped classroom (BT-FC).

Resumen

Los laboratorios vivientes son instrumentos clave para introducir nuevos enfoques pedagógicos en la formación de estudiantes de arquitectura mediante el diseño, construcción y operación de prototipos experimentales de viviendas sostenibles. En los últimos años, el desarrollo de estos laboratorios orientados a la educación e investigación en la educación superior se ha vinculado con el Solar Decathlon Europe (SDE), concurso internacional de universidades para diseñar, construir y operar casas solares autosuficientes. Uno de estos prototipos, dirigido por el autor desde 2012, brinda a estudiantes locales e internacionales una experiencia transformadora en vivienda sostenible, energía y estilo de vida. La investigación educativa confirma su aporte positivo a la educación transformadora para la sostenibilidad.

Palabras clave: aprendizaje transformador, living labs, educación para la sostenibilidad, enfoque construcción-aprendizaje, descarbonización.

Bloques temáticos: espacios para el aprendizaje, aprendizaje cooperativo (AC), design/build, blended teaching y flipped classroom (BT-FC).

Resumen datos académicos

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Nivel/curso dentro de la titulación: 4/5 año

Denominación oficial asignatura, experiencia docente, acción: Asignatura optativa LOW3: Living Zero!, 5 ECTS

Departamento/s o área/s de conocimiento: Departamento de Tecnología en la Arquitectura

Número profesorado: 1

Número estudiantes: 20 por quadrimestre

Número de cursos impartidos: 10+

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Introduction

Higher education institutions (HEIs) are important stakeholders in the process of sustainable transformation of society on three levels: through educating professionals as future societal leaders and so-called game changers; through their communities, exemplifying the transition of society, e.g. campus operation and impact reduction; and through their outreach to society, facilitating knowledge for action and influencing the societal practices of production and consumption. Universities can therefore be considered effective agents of change (Svanström et al. 2008).

The underlying holistic transformation process of HEIs includes a necessary redefinition of learning outcomes of academic educational programs, new methodologies of teaching and learning and the overall redefinition of HE learning environments.

Real-world, collective and experience-based approaches have been shown to be powerful in this context, as learning on sustainability is not limited to the acquisition of specific knowledge, but rather needs a radical shift of focus, which can be achieved through interdisciplinary collaboration and exchange, value discussion, as well as real experiences of behavioural change (Ankrah et al. 2023). Concepts like “unlearning” are linked to the need to get out of routines to experience new habits and new ways of doing things. All of these processes need time and places to be implemented, experienced and optimized in order to be fully integrated into educational environments (Barth et al. 2023).

In this holistic transformation, the concept of living labs at universities can have a major impact, as it connects people, disciplines and physical places and has the potential to create ecosystems of transition between university and any kind of public or private societal stakeholders (Masseck 2017).

Living Labs

According to European Network of Living Labs (ENoLL), “a living lab is a real-life test and experimentation environment where users and producers co-create innovations”, with four main activities typically employed by living labs:

- Co-creation: co-design by users and producers
- Exploration: discovering emerging usages, behaviours and market opportunities
- Experimentation: implementing live scenarios within communities of users
- Evaluation: assessment of concepts, products, and services according to socio-ergonomic, socio-cognitive, and socio-economic criteria.

Main characteristics of living labs are their multi stakeholder approach, often based on a PPP (Public-Private-Partnership); the focus on user involvement, giving a special role to the user as part of the innovation process; Open Innovation, considering innovation as an open process with multiple stakeholders; and the setting in a real-life environment, experimenting and capturing user insights in real-life situations.

Living labs can even be developed on an urban scale, dealing with the immense social, environmental and economic complexity of sustainable urban transformations (Morales, 2023).

Solar Decathlon prototypes as living labs

At the Valles School of Architecture (ETSAV), living labs play a major role specifically as instruments allowing the introduction of new pedagogical approaches in the education of architecture students through designing, building and operating experimental sustainable housing prototypes.

The development of these living labs is closely tied to the Solar Decathlon Europe (SDE) Competition—a university contest for solar-powered, energy-efficient houses. Originating in the U.S., SDE has held four editions in Europe since 2010, with UPC participating each time. In this event, teams of 50–100 students from various disciplines—including architecture and engineering—work together with companies, faculty, and consultants to design and build full-scale prototype homes. Projects emphasize sustainable housing innovation and energy independence through both active and passive solar approaches, producing real results and valuable experience within a two-year timeframe.

This collective, cross-disciplinary process stands out as an intense and successful educational experience, advancing holistic sustainability approaches in the fields of housing, energy and life style. Beyond the technical design of projects, SDE teams examine issues like sufficiency, shared living, quality of life, and connections between consumption and well-being, while piloting new models such as co-housing and compact dwellings with real prototypes.

In the context of Solar Decathlon competitions a living lab can be understood as a place where construction, monitoring and evaluation can happen at one place, through a multi stakeholder approach (students, researcher, companies, administration, general public), in a co-creation or open innovation process, allowing for user-centred research under real conditions of use (house occupancy experiments) and real-time feedback about performance data, user comfort, user-building interaction, energy management, energy efficiency, and many related field of interest in the holistic search for truly sustainable housing concepts of the future.

Analysing the post-competition use of Solar Decathlon prototypes, one important question is the overall lifespan of the projects. Many of them are no longer operative after the competition. Others have found their use for a longer period of years within a university context, e.g., as residence buildings under permanent occupation, and still maintain their living lab characters due to guided visits, ongoing performance evaluation or as part of a local energy grid.

Some prototypes show very low activity during a longer period after competitions, before being activated and used again and others get immediately reconstructed and used for ongoing teaching, research or dissemination activities. This often depends on how the after-competition use phase has been planned beforehand and important aspects like final location, use rights, maintenance and management have been clarified and corresponding agreements have been closed among partners.

In the after-competition use phase some projects seem to focus more on research activities, others foster specifically educational initiatives, and many of them maintain a mix between both. Therefore, a clear distinction between research and educational living labs cannot be easily made. Reality shows a huge variety of possible after-competition uses, and only a closer analysis of a specific project can reveal its unique mixture between educational and research activities. Over the lifecycle the focus and intensity of activities also tends to change, as e.g., research on technological components of prototypes is generally done in the first 2-3 years after competition and then tends to decrease.

This leads to the conclusion that most projects might start as a research living lab, with educational activities, shifting over time towards an educational living lab with some research activities still going on.

The LOW3 living lab

The LOW3 living lab, based on UPC's 2010 SDE entry and reconstructed at ETSAV's campus, has since then supported a wide range of educational activities—from undergraduate courses to PhD seminars—and practical experiments like the “Live at LOW3” experiment, evaluating its overall function and impact as student housing under real conditions of use. Additionally, LOW3 has hosted networking and research events focused on sustainable living. Over a decade, its multifaceted use has confirmed the value of LOW3 as a transdisciplinary lab for learning, research, and innovation in sustainability.

The prototype operates since 2012 as a platform exploring new formats of teaching sustainability through participatory teaching and learning approaches.

Its main teaching innovation approach is influenced by the concept of user involvement in research and innovation, derived from the definition of living labs as places for co-creation and open innovation in real-life settings through a multi stakeholder approach (academia, companies and research entities but also local administration), understanding both students, researchers as well as citizens as the “users” of this newly generated platform (Masseck 2013).

In consequence the LOW3 living lab is an activities platform with a participatory approach to teaching and learning based on a prototype solar house, offering its spaces, its equipment and its infrastructure to diverse user groups from both inside and outside UPC.

Teaching and learning activities take place in parallel with research projects and outreach activities in order to create synergies between sectors, people and disciplines. Finally LOW3 is also a place for the networking of people in order to engage in new sustainability projects and initiatives, fostering the human factor behind these activities.

Regarding its current academic offer, the regular elective course LOW3: Living Zero! (5 ECTS) consists in the combination of theory and project related learning by doing in the fields of housing energy and lifestyle. As teaching innovation project it aims at transformative learning for a model of society and a personal lifestyle with less environmental impact. The main objective of the course is to introduce to basic sustainability concepts by exploring the LOW3 prototype and its solutions in the fields of housing, energy and lifestyle.

The course is based on a blended learning format, virtual and face-to-face, by combining the concept of an online course (MOOC) with face-to-face sessions at the LOW3 living lab. The exercises of the course are linked to the evaluation and improvement of the environmental impact of the housing and lifestyle of the participants, as well as to research projects such as the international project Sustainable Lifestyles Accelerator (SUSLA) or WISER about waste-based shading devices. Since 2021, the Green Office ETSAV initiative has been integrated into the course and focuses on the green transformation of the Campus and the community in order to create a disruptive and inspiring experience that combines the acquisition of knowledge, the discussion of values and the execution of real projects around sustainability through a transformative learning model.

Methodology

The applied methodologies and tools of the LOW3 living lab course facilitate students' learning about different aspects of sustainability in an impactful way by

- Exploring, experiencing, and measuring a sustainable housing prototype. (Strategy 1)
- Learning self-paced online through weekly modules (MOOC) on the digital platform of the course. (Strategy 2)
- Participating in regular debates and exchange of personal experiences together with value discussions related to the topics of the online modules. (Strategy 3)
- Designing, planning, self-organizing and executing collectively a specific project in a team. (Strategy 4)
- Communicating knowledge, projects and results to the community (regular posts, podcast series, in-person activities). (Strategy 5)

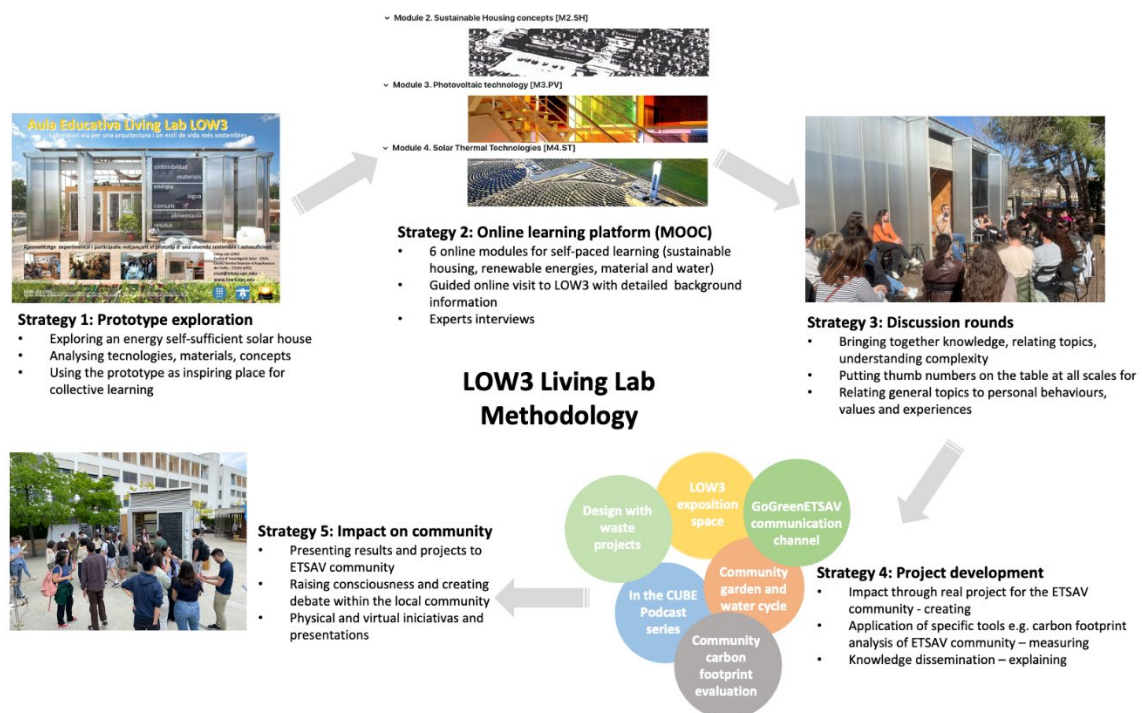


Fig. 1 LOW3 Living Lab Methodology. Source: own elaboration

The practical part of the course (Strategy 4), introduced and strengthened since 2020, focuses then on a real project, designed, developed and build by students with support of the campus building workshops and the LOW3 living lab infrastructure regarding tools, materials and execution. Its aim is to work in teams on specific topics, with a physical execution of prototypes, maintenance and improvement works related to the LOW3 prototype house, the community garden project, or expositions and material collections related to the topic of each course.

The communication part of the course (Strategy 5) has been strengthened since 2021 and focuses on the dissemination of knowledge to the ETSAV community and beyond through social

media channels, podcasts and events. Through the collaboration with Green Building Council Spain (GBCE), and with the aim to strengthen knowledge on decarbonization among students of architecture, knowledge, tools and projects of GBCE have been disseminated and students of the course participated in webinars and events organized by GBCE.

All strategies together aim to create a transformative learning experience for students, generating real impact at different scales and cognitive levels combined within a social group experience.

To measure the transformative effect of the educational initiative on participants and to document and evaluate the impact on their sustainability literacy, value shift and behavioral change, the following qualitative and quantitative evaluations have been carried out:

- Personal conversations and feedback
- Questionnaires at the end of each course
- Pre- and post-tests, evaluating specific sustainability knowledge
- Self-evaluation tool of the online learning platform

Activities

During the past two academic years, course projects focused on designing and building with repurposed waste materials. Students actively supported a national funded research project by working together with other faculties and courses to create mock-ups of novel construction solutions (Masseck 2024). This collaboration sparked new projects, including making furniture from recycled materials and organizing an exhibition at LOW3 to highlight the reuse potential of construction and demolition waste in buildings. A first step consisted in sourcing waste on and off campus, gathering together waste materials from nearby building sites (Figure.2).



Fig. 2 Waste sourcing on and off campus. Source: Masseck, T. (2023)

The analysis of type, quality and properties of different sourced waste materials and a desk study of similar projects, initiated the co-design phase with regular meetings, reviews and presentation (Figure 3).



Fig. 3 Design of waste-based shading devices. Source: Masseck, T. (2023)

The collaboration with 2 other courses working on the same topic, allowed for 2 common review sessions with invited experts and the development of an assessment scheme with a set of corresponding indicators, giving feedback to all student teams (Figure 4).



Fig. 4 Review of proposals and mock-ups with invited experts. Source: Masseck, T. (2023)

After selecting 3 promising proposals, the whole course concentrated on the final design and construction of the corresponding 1:1 prototypes, using the fabrication workshop at the campus (Figure 5).



Fig. 5 Construction works of 1:1 scale waste-based shading devices. Source: Masseck, T. (2023)

Finally prototypes have been exposed and presented to colleagues and fellow students at a final event at the LOW3 living lab. Mechanisms could be tested and presentations were held with detailed analysis of environmental impact, CO₂ savings and overall performance (Figure 6).



Fig. 6 Exposition and testing of shading devices at LOW3. Source: Masseck, T. (2023)

Additionally, students renovated the interior of the LOW3 living lab to transform it into a space for exhibitions of waste materials and other place for other activities at ETSAV. They also designed and built a pergola using reclaimed materials, providing shade for the LOW3 solar house's terrace and making it more usable during hot periods. The campus community garden was also revitalized, with improvements made to its irrigation system, rounding up the personal experience regarding more sustainable lifestyles (Figure 7).



Fig. 7 Refurbishment of LOW3 spaces for community use. Source: Masseck, T. (2023)

Each course generates additionally impact towards the whole academic community by organizing a event which spreads information on decarbonization in general, and presents the work generated by the students (Figure 8).



Fig. 8 Dissemination event towards ETSAV community. Source: Masseck, T. (2023)

The final delivery of prototypes and the corresponding design materials contributed to the further development of the linked national research project for the development of waste-based shading devices (Figure 9).



Fig. 9 Project outcomes waste-based prototypes. Authors: LOW3 students 2023/24. Source: Masseck, T. (2023)

Results

From the teachers point of view, and beyond the individual transformational learning experiences of students, the following outcomes and obstacles could be identified regarding a collective sustainability transition of the academic community.

Achieved outcomes:

- Successful collaboration between disciplines, faculties and courses through links to national and international research projects.
- Creation of an unformal learning environment for meeting and socializing, new initiatives and place of resilience for the community.
- Intercultural exchange between international and local students, facilitating value discussions and knowledge exchange across different cultural backgrounds.
- Contribution to campus facilities through the ongoing improvement and conditioning of the living lab and its surrounding.

Observed obstacles:

- Continuity of practical projects is complicated, due to change of students each semester.
- Interculturality and English teaching language are generally positive, but might be hindering for some local students.
- As an elective subject the course is not principal study focus of students resulting in limited dedication in time and reduced outcomes.
- Link to research projects is desirable, but increases complexity and effort for management of collective sessions, timing, deliveries.
- Practical construction works imply security aspects, knowledge on use of tools and machinery and depend on abilities of students.
- Self-organization of projects by students is challenging and results depend on their motivation, skills, interpersonal qualities and personal circumstances.

This presented living lab course is based on the principles of "Learning by doing", which requires students to be proactive, propose initiatives, define objectives, procure for necessary resources, execution, completion and presentation of their projects. Regarding the necessary student engagement the following observations can be made:

- Students profile and behavior changed over time: engagement differs from course to course but generally said, over the last 10 years students seem to get less compromised and engaged. One reason might be that local students are immerse in their studies and often work additionally, so Little or no extra engagement can be expected beyond class hours, e.g. regarding activities towards the community, webinars or the final GBCE events.
- International students are enriching essentially the course through their contributions based on their different cultural backgrounds. Regarding their engagement they can be 'drivers' or 'drop outs' of the course, means that some are totally committed, but others fail in assistance and contribution.

Transformative learning

The evaluation of results regarding the degree of achievement of a truly transformative learning experience needs discussion, relying so fare mainly on qualitative results as indictors of success.

Students report in conversations and through the questionnaire at the end of the course that the specific projects have given them personal satisfaction by building and transforming physically their environment together with the experience of teaming up with others and self-organizing objectives, work, schedule and outcomes.

A pre- and post-test with 20 essential questions about sustainability definitions and facts has been done by a total of 40 students at the beginning and the end of the courses, showing a slight increase of their capacity of understanding and explaining sustainability related concepts. Nevertheless, results are difficult to interpret in terms of transformative learning, as they basically reflect the ability of understanding concepts and retaining knowledge.

Regarding their overall experience, in the final questionnaire of course 2023/24, students gave the following comments:

- *For me, the modules and the videos of the MOOC platform were so useful for learning specific things about sustainability, I think that there was a good coordination between the theoretical part and the practical part.*
- *The platform was very organized and it was very intuitive to access all the features.*
- *The university should explore this kind of approach on teaching architecture or any other topic. Fast modules at home to later debate at class and work on them. It was very pleasant.*
- *The possibility of doing a group project, having the creative freedom to put ideas into practice, which contribute to the house, sharing the projects and course information, was very positive.*
- *I really enjoyed my experience in the LOW3 course because we have applied a mixed learning: online, in presence all together in class, and also manual work. This is much better than the regular and conventional lessons.*
- *Very nice and valuable elective course. I wish something like that would be offered in my home university.*

Nevertheless, real transformative impact in students can most probably only be measured or observed over time, as it is generated later, in follow-up projects of participants, when the acquired profound knowledge about sustainability and an increased consciousness of the urgency for change and transition materialize in different way of engaging in projects and focusing on solutions.

Regarding this long-term evaluation it can be stated that:

- A considerable number of early participants in the LOW3 project have successfully developed their professional and academic career in the field of sustainable architecture, creating own cooperatives or collaborating in offices or public administration
- Approximately the half of the current Master students of the MISMEC – double degree program at ETSAV. focused on sustainability, have been students in one of the LOW3 courses which might indicate that the course has fostered their interest in sustainability

Interviews with former students might shed further light on the real impact of this specific teaching program in their academic and professional careers as well as in their personal values and beliefs regarding sustainability.

As positive outcomes regarding the generation of educational networks around living labs like LOW3 can be stated:

- The creation of student networks which often started during the competition phase and persisted in the post-competition phase resulting in a common profession projects like a start-up or a cooperative.
- The creation of research networks which allow generating research and innovation outcomes in and around the prototypes.
- The creation of institutional networks which keep supporting the project in the post-competition phase, and as stakeholders support e.g. a new participation in a later competition or a similar project on local or regional level.

Conclusions

Transformative learning experiences are relevant for accelerating change in values, behavior, and knowledge of future professionals. Academic living labs like the presented initiative can contribute as places for such holistic impact-full ways of learning in an academic environment and beyond. How to improve, measure and evaluate results, is an ongoing matter of research.

The LOW3 project has essentially contributed to the transformation of teaching at the ETSAV, has inspired all subsequent Solar Decathlon Europe initiatives (2012, 2014, 2019) and has introduced a unique site on the ETSAV campus that allows learning through the exploration of a prototype on a 1:1 scale, using the site as a didactic space for a transformative experience, learning by doing, where the challenges, options and values related to the transformation of society towards sustainability can be discussed in an inviting, almost domestic atmosphere, and practical design work allows putting into practice theoretical approaches e.g. regarding the re-use of waste materials in the building sector,

As an elective course, the LOW3 living lab is based, like many similar initiatives, on the personal effort of its academic responsible, but does not receive official recognition as academic activity. This contrasts with the need for teaching innovation and the use of sustainability related projects to the benefit of university, attracting local and international students.

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