62. Teaching Sustainability through Living Labs in Architecture: The case study of the UPC-LOW3 prototype solar house

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Abstract

Sustainability is currently one of the most important issues to be integrated at all levels of teaching from kindergarten through to university up to lifelong learning activities of society as a whole. Specific disciplinary knowledge should be taught by adopting a holistic method, with a transdisciplinary approach towards the environmental, economic and social aspects of sustainability. The term "Sustainability Science" describes the corresponding concepts and methodologies. Within the career of Architecture and Architecture-related disciplines, new teaching formats are needed for this holistic approach for knowledge generation and transmission. Living Labs in architecture can be tools towards achieving a holistic approach in teaching sustainability, using real built environments for user-centred research and collaborative learning in a university campus. LOW3 is the 2010 Solar Decathlon Europe solar house of UPC Barcelona Tech that since 2011 serves as Living Lab at the ETSAV campus at Sant Cugat del Vallés (Barcelona). As a Net Zero Energy Building (NZEB), Living Lab LOW3 allows active teaching, research and innovation activities in the field of sustainable architecture and lifestyle. The present article describes the different stages of implementation of Living Lab LOW3 at the campus, a first evaluation of teaching and applied research activities through questionnaires and interviews with the participants and a critical analysis of the overall project concept. It shows that after 2 years of step-by-step implementation, Living Lab LOW3 has greatly contributed to a holistic-based sustainability education at the ETSAV School of Architecture. The knowledge generated was broadly disseminated and important generic competences were fostered through the project. Living Lab LOW3 is an ongoing project, which aims to innovate in sustainability education. Its outcomes and lessons learned can serve as an example for similar activities at other universities.

Key words: Solar Architecture, Teaching, Sustainability, Living Labs, Net Zero Energy Buildings, Collaborative Learning Environments, User-centred Research and Innovation

1 Introduction

Our society nowadays needs a redefinition of its productive model that integrates bottom-up environmental, economical and social aspects of sustainability. Radical changes towards Net Zero Energy Buildings and consideration for much more energy efficient lifestyles are urgently required. Holistic thinking professionals with well-developed generic competences are needed to solve complex problems.

By employing a holistic view to our complex environmental, economical and societal systems and their corresponding interrelations, Sustainability Science – a new holistic and scientific model – could be the right approach to address the problems of today's society. Sustainability Science focuses on the

complex and dynamic interactions between society and nature and is based on transdisciplinarity, integrated analysis and the development of knowledge for action (Komiyama et al. 2011).

In order to transfer this new scientific approach to the academic world, multi-stakeholder collaborations between university, society and companies must be intensified thereby fostering synergies in the fields of learning, research and innovation in the field of sustainability.

1.1 State of the art – Living Labs for Architecture and Lifestyle

Existing laboratories for building construction, building physics or technological research and development traditionally focus on specific areas of knowledge and less on a holistic multidisciplinary approach. They therefore have limited capacity to generate relevant output in fields of research where user interaction is an important factor. For example, regarding the user acceptance of technology, user-technology interaction or the field of a holistic impact analysis of technological innovations on life-style and society. The development of "Living Labs" has been a step forward in bridging this gap.

Living Labs or living laboratories are defined as real world environments which focus on user-centred research and user co-creation with the aim of accelerating innovation processes (Almirall & Wareham, 2008). In the late 1990's the term Living Lab was first used for innovation activities related to ICT, such as mobile appliances for improving elderly healthcare or improvements in proceedings and work flows in city administrations. Using real world environments for implementation, evaluation and improvement cycles they then allowed the development of the first solutions within an iterative process towards a final product, application or service (Almirall & Wareham, 2008).

With regard to the Living Lab approach, several Living Lab networks and platforms have been founded since approximately the year 2000.

One of the fastest growing networks of Living Labs is the ENoLL (European Network of Living Labs). It was founded in 2006 and today (May 2013) has more than 450 Living Lab initiatives linked to it. EnOLL describes the need for Living Labs with the necessity of fastening the market availability of innovations through user-centred research and user co-creation (Open Living Labs. The First Step Towards a New Innovation System, 2013). These concepts are based on the idea that, through immediate user feedback in real world environments, researchers and developers in collaboration with users are able to create and improve innovations and assure market viability within very short periods. This is an efficient alternative to traditional research and innovation processes. Only a small part of the ENoLL initiatives are focused on sustainable architecture and lifestyle, with a strong emphasis on social research and a culture of change.

In the last years, specific research and innovation infrastructures and projects have been created that focus on Net Zero Energy Buildings (NZEB) and Sustainable Lifestyle. One is the Norwegian Research Centre on Zero Emission Buildings at NTNU (Trondheim, Norway). It focuses not only on zero emission technologies but also on user behaviour and lifestyle (ZEB - the Research Centre of Zero Emission Buildings, 2013).

Another important initiative is the LIVING LAB project, a funded European FP7 project for Living Labs, directed by the Wupperthal Institute which had the idea of creating a network of standardized living labs in different climatic and social-economic environments in Europe, thereby allowing the comparison of results through similar physical settings (Liedtke et al, 2012).

Since 2002, the international Solar Decathlon competition promotes the development of energy self-sufficient solar houses by universities; fostering during the latest competitions, especially in Europe, a holistic view on sustainable architecture, including the aspects of urban density, shared facilities and

infrastructure as well as energetic renovation processes. More than 120 prototypes have been developed and built during the last decade (Solar Decathlon 2010: UPC, 2010).

The efficiency of the Living Lab approach, together with the transdisciplinary and holistic concept of the Solar Decathlon solar houses, invite one to analyze the potential of these prototypes being converted into living laboratories in the field of sustainable architecture and lifestyle.

The present article describes the case study of a widened concept for a Living Lab in architecture: linking innovation to collaborative learning and co-creation activities, fostering synergies between the knowledge triangle of teaching, research and innovation in the field of sustainable housing and lifestyle.

1.2 Background

The ETSAV School of Architecture of UPC-Barcelona Tech regularly contributes to important innovations in teaching strategies towards participating models. They, in turn, foster the generic competences of students and look for interaction with the local socio-economic environment of the school.

Since 2008, one of the projects with a mayor impact has been participation in the Solar Decathlon Europe competition, starting with the 2010 prototype solar house LOW3. Today LOW3 is a Living Lab at the campus and serves as a place for implementing Living Lab strategies and activities, integrating all three fields of teaching, research, and innovation.

The main hypothesis of the Living Lab LOW3 project is that the establishment of Living Labs in architecture as collaborative learning environments, innovation arenas, and places of social interchange, learning and progress can be a mayor contribution to a holistic and effective education in sustainability at schools of architecture and beyond.

1.3 Research Questions

Considering Living Labs based on prototype buildings as new tools or infrastructures within academia, with a special focus on architecture and architecture-related disciplines, the main questions for this ongoing research work are the following:

Is the use of Living Labs in architecture useful and efficient for education in sustainability and a holistic knowledge about architecture, technology and lifestyle?

Which activities can be efficiently linked to a Living Lab, and which generic and specific competences can be better attended to through the Living Lab approach compared to traditional teaching formats?

How can a teaching and research infrastructure like a Living Lab be created, financed, managed and maintained within the administrative and academic context of a university?

What are the lessons learned and future recommendations of the Living Lab LOW3 project at UPC – Barcelona Tech?

2 Methodology

2.1 Type of research

The methodology applied for analysing the Living Lab approach of the LOW3 project is based on participatory action research with a regular analysis of activities, evolution, and outcomes. This way,

we can evaluate the success of all related initiatives and their contribution to the holistic overall Living Lab concept.

The documentation of activities, enquiries and interviews of participants and stakeholders, as well as the development of Living Lab indicators, are further tools for the analysis of progress and outcomes.

A comparison with similar projects - such as the HOME+ prototype of Hochschule für Technik (HfT) Stuttgart, or the 2007 and 2009 SD solar houses of Universität Darmstadt as well as other similar Living Lab projects all over the world - will allow a critical discussion of the achieved results.

2.2 Object of research –living lab activities

The main focus of the present research work is the analysis of the development, implementation and activation of the Living Lab LOW3 project since the end of the SDE 2010 competition. Three official Living Lab LOW3 courses and several complementary activities have been completed since then. Figure 1 shows the development over time of Living Lab LOW3 project and its related activities.

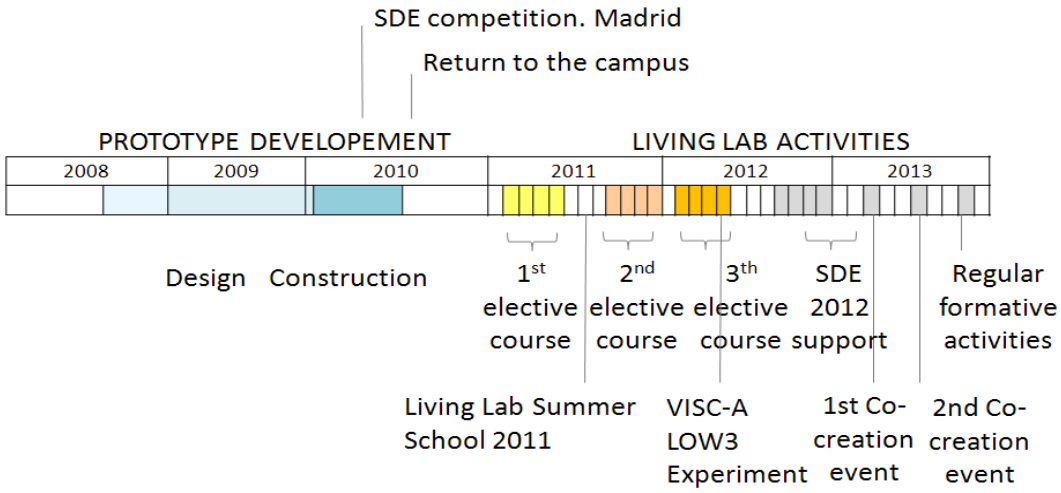

Figure 1: Development over time of the Living Lab concept of Living Lab LOW3

Main activities since 2011:

- Living Lab LOW3 course 2011: re-construction, installation works, analysis, first measurements of the LOW3 prototype solar house at the campus
- Living Lab LOW3 course 2011/12: installation works, bioclimatic measurements, holistic evaluation, knowledge dissemination
- Living Lab course 2012: LIVE AT LOW3 experiment – activity based on user-centred research: house occupation with 2 students during 2 weeks and holistic evaluation of their lifestyle and impact through the participating student team
- Related final career projects, Master and PhD thesis work: Natural ventilation in buildings (2011), The house management system of LOW3 (2012), Personal Learning Environments (2012), Grey water recycling materials (2012) and Living Labs in Architecture (2012)
- 1st co-creation and innovation seminar: activities platform for new student projects, initiatives and participatory research activities (2013)
- Collaboration in industrial research project on concentrated solar power systems and energy storage in buildings (2013)
- Several other activities related to teaching, projects and dissemination with more than 1200 participants in more than 2 years

Figure 2 shows the diverse activities linked to the Living Lab LOW3 project, from formal teaching and applied research activities, to social events, knowledge dissemination and less formal co-learning activities.

Figure 2: Living Lab LOW: Teaching, research and Innovation activities regarding sustainable architecture and lifestyle

Each activity has been documented. An individual analysis and evaluation has been carried out in order to evaluate the success of each initiative, analyse the lessons learned, and gather information about possible improvements.

2.3 Indicators

One important issue for the comparison and the overall evaluation of the success of the Living Lab initiatives is to find the right indicators for the evaluation of a Living Lab approach in Architecture as a holistic project for teaching, research and innovation. During the analysis of similar projects, with a special focus on the post-competition use of Solar Decathlon solar houses, the following main indicators for success and impact of Architecture Living Labs have been identified:

- Total amount of stakeholders involved: number of persons, companies and public institutions linked to the project
- Transdisciplinarity: number of different disciplines involved into the project
- User-centred innovation and co-creation activities: Type and amount of activities linked
- Outcome: Publications of results such as communications in congresses, thesis work related, articles
- Financial concept and support: total amount of funding and type of stakeholder contracts

These indicators are a first approach for the analysis and comparison of Living Lab initiatives and will be further developed, weighted and discussed in future research.

2.4 Regular questionnaires of students

Regular questionnaires were given to students at the start and after finishing the Living Lab courses. These serve to: obtain and analyse the feedback about the concept of each course, determine which competences students consider important at the start of the course, and to see whether these identified competences became strengthened through the Living Lab approach. Opinions given about deficits perceived by students regarding their regular studies and possible improvements through the use of Living Lab completed the questionnaires.

Table 1 shows an example of the initial questionnaire of the 2011 and 2012 Living Lab courses.

Table 1: Extract of participant initial questionnaire Living Lab LOW3 2011 and 2012

A. For your future work life, which competences, abilities and knowledge do you think are most important?	Teamwork abilities and communication skills
	Transdisciplinary communication and understanding
	Holistic view and specific knowledge on sustainability
	Use of virtual learning environments and resources
B. What do you think a Living Lab in Architecture could stand for?	Collaborative and participatory learning environment
	Transdisciplinary teaching and research in sustainability
	Holistic education on sustainable construction and energy efficiency
	Platform for user co-creation and innovation
C. What aspects of your current studies do you think could be significantly improved through a Living Lab at the campus?	Practical construction and evaluation experience
	Transdisciplinary work experience
	Project based learning on a real building
	Interactive Learning Platform virtual/presential

After finishing the course, Living Lab students were asked to which degree (1-5 scale) the course would have attended the previously identified competences, knowledge and other aspects. Figure 3 shows an example of answers given by the 38 participating students of the 2011/12 and 2012 Living Lab courses regarding competences in teamwork, leadership and decision-making.

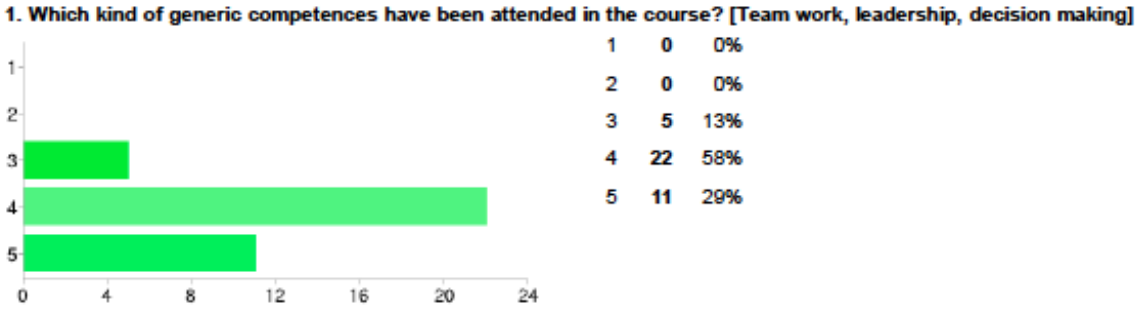

Figure 3: Example of results of participant's enquiries about the Living Lab course and the attended competences regarding teamwork, leadership and decision-making

Interviews were conducted with the participants to discuss special issues such as their personal learning environments. Additionally, open group conversations were held after concluding each activity for feedback on its success, critics and proposals for improvement.

3 Results

The following results of the research conducted show the outcomes of the Living Lab LOW3 project within its university context.

3.1 Teaching Sustainability through Living Lab courses

All three Living Lab courses held since 2011 proved to be highly participative, developing many generic competences, skills and knowledge of students that had to collaborate and co-design the individual objectives and working plans for each course. The questionnaires confirmed that competences such as transdisciplinary collaboration and understanding (valued 3,46 in a 1 to 5 scale), a holistic view and specific knowledge on sustainability (valued 3,86) and especially teamwork and communication skills (valued 4,05) have been fostered broadly throughout the course.

The students identified the following special qualities common to all Living Lab courses, differentiating them from other regular teaching formats: The transdisciplinary teaching and research approach (3,84), and especially the collaborative and participatory learning environment (valued 4,22). They further valued positively the project-based learning approach related to a real building (valued 3,86) and the practical construction and evaluation experience (3,92).

Self-organization of different construction and installation works as well as monitoring activities demanded a real commitment from each participant. This caused minor conflicts due to time intensive nature of works out of regular schedule, for example regarding the collaboration with external experts or installers. Different individual attitudes of students towards the common goal of the courses also caused some tensions.

3.2 Live-at-LOW3 Experiment

The ‘Live-at-LOW3’ experiment of the 2012 course needed a special commitment of the participating students. No regular timetable could be guaranteed during the course. The house-occupation experiment has been a holistic approach to user-centred research. A pair of students evaluated and tested the prototype solar house during 14 days with the participating course students accompanying and evaluating the experiment through monitoring and lifestyle evaluation of the inhabitants with a holistic view on housing, consumption, food and mobility.

Results were published in research documents, the experiment was filmed and published through a documentary as well as local newspapers and television showed interest in the experiment and its outcomes.

A holistic learning and user-centred research process could be conducted with interesting results. A wider engagement of the academic community, as well as society in general, could be achieved through open door days, media interest (national and local TV and radio emissions, digital newspapers) and the use of social networks and ICT (youtube channel for video diary, documentary, live webcam).

3.3 Management, financing, stakeholder participation and indicators

A Living Lab like LOW3 at a university campus is a complex infrastructure that needs regular funding for its installation, maintenance and management. Stakeholders like local, public administration and

private companies are ideal partners to contribute to their diversity and the necessary funding. Organizational difficulties can arise regarding responsibility, university regulations, maintenance costs, property rights, and many other aspects.

LOW3, as with many other Solar Decathlon projects, lacked resources. After the competition voluntary student collaborations, interest from the university, and media attention retreated, accompanied by a peak of exhaustion of administrative staff and collaborators. No clear planning for the "after use" of the project was developed before and during the SDE competition.

All stakeholder participations, teaching and applied research activities as well as co-creation seminars and additional initiatives have been organized step-by-step after the competition.

Indicators are important instruments to assess the performance of a Living Lab. The number of students, teaching staff, researchers and stakeholders involved, number of projects and activities linked, documents generated (reports, documentaries), people reached (open doors day, news on television, publications in newspapers, visits on website and blog, newsletters etc.) are some of the indicators that really confirm the contribution of the project to the school's academic profile, and will help to compare Living Lab LOW3 with other similar living lab projects.

4 Discussion

After more than 2 years of implementation, field experience and continuous evaluation, the following lessons could be learned from the Living Lab LOW3 project:

- SDE prototype houses like LOW3 are ideal objects to be converted into Living Labs for sustainable architecture and lifestyle at universities, but proven methodologies and documented experiences on strategies, tools and outcomes are still rare.
- Students value positively the innovative teaching approach and especially the participatory teaching model of the Living Lab LOW3 courses, but also ask for clear course structures.
- Living Lab LOW3 facilitates the generation of participatory co-learning activities that allow collectively generating and distributing new knowledge. A dynamic learning environment with formal and informal activities from workshops and seminars up to co-creation sessions, user-centred research activities and knowledge dissemination for the general public has been created.
- The development of ICT technologies and societal changes are happening today very fast and universities need to respond to these phenomena (new teaching subjects like NZEBs or smart cities, collaborative learning environments, e-learning, MOOCs, social media, social networks). Living Lab LOW3 shows itself to be an ideal infrastructure for experimenting and integrating these issues into the academic agenda.
- University organizations need to adjust some of their organizational structures and administrative mechanisms to handle smoothly activities like SDE, Living Labs or similar projects regarding organization, financing, management and integration in curricula.
- Indicators are needed to describe and compare Living Lab projects and their structure, allowing benchmarking of different Living Lab initiatives.

5 Conclusions

Sustainability science in research and education is still a young discipline and it is in constant flux and evolution. Transdisciplinary thinking and collaboration are fields yet to be developed within our disciplinary-organized universities.

Collaboration, co-creation or synergies cannot be forced to happen within the diverse academic context of universities. Nevertheless, places and infrastructures can be created that facilitate these

essential educational processes. This seems to be one of the most important contributions that Living Labs can make to Architecture.

Further development of this relatively new Living Lab approach is necessary. Methodologies and tools are in constant change, and experiences on a national and an international level will generate new knowledge that helps evolve the initial concepts.

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