LIVING LAB LOW3 – AN INNOVATIVE TEACHING CONCEPT FOR SUSTAINABLE ARCHITECTURE AT UPC-BARCELONA TECH

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Abstract

The LOW3 (low energy – low impact – low cost) prototype developed by UPC-Barcelona Tech for the Solar Decathlon Europe 2010 competition is a energy self sufficient solar house or *Net Zero Energy Building* based on three main principles: a *low energy* demand, a *low impact* on environment and a *low cost* architecture with a strong focus on the economy of means.

LOW3 explores the thermal capacity of intermediate spaces in contributing to a low energy architecture as well as it explores spatial qualities, creating in-between spaces for innovative ways of living.

LOW3 has been realized in a 2 years process with the participation of over 100 students and 50 companies, winning a first prize in the category “Architecture” of the Solar Decathlon Europe 2010 competition.

At this moment the prototype solar house gets converted into a *Living Lab* LOW3 platform at the UPC campus at Sant Cugat, Barcelona.

Living Lab LOW3 will become an innovative education tool for sustainable architecture, energy efficiency and renewable energies within an international framework.

The main objective is to foster experience based learning, co-creation and collaborative learning processes in the field of energy efficiency, bioclimatic architecture, solar systems and sustainable construction based on the experimental analysis, development and evaluation of prototypes.

Living Lab LOW3 started at January 2011 with a first learning module, involving 20 students in the construction and evaluation of the prototype together with experts from companies and university staff.

The course integrates Master and PhD students with the aim to link teaching and research activities.

First results of this innovative teaching concept show the importance of experienced based learning and the potential of building prototypes as combined research and learning facilities towards a holistic education in sustainable architecture.

Living Lab LOW3 is the latest step in a row of teaching activities in solar architecture based on transdisciplinarity and participation, initiated by the Solar Research Centre (CISOL) of the Vallès School of Architecture (ETSAV) of UPC-Barcelona Tech since 2003.

A comparison of 5 different applied teaching formats shows the great potential of Living Labs in Architecture regarding the implementation of competence-based teaching according to the objectives of the EHEA (European Higher Education Area) and the acquisition of specific knowledge and skills in the field of sustainability in architecture.

Keywords

Solar Architecture, Net Zero Energy Buildings, Living Labs, Collaborative Learning, Experience Based Learning, Integrated Energy Design

1. Introduction

The architecture sector, as well as almost all other research and production areas in our industrialized society, is nowadays focused on the urgent necessity to create knowledge and innovation regarding to their radical change towards sustainability.

In the fields of innovation and progress in architecture, urban planning and construction technologies, architecture schools have always played a major role as think tanks, places of education and research.

Considering the complexity of today's environmental challenges like resource shortage, greenhouse gas emissions and destruction of biodiversity, the related socio-economic conflicts, and the subsequent need for basic changes, new tools are actually necessary to make innovation processes more efficient, linking them to teaching and research activities and allowing interdisciplinary approaches.

From a socio-economic and political level, especially within the European context, specific targets are set, for example through the Energy Performance of Buildings Directive (EPBD) 2010/31/EU which demands that new buildings will have to be *nearly zero energy buildings* by 31st December 2019 with public buildings having to fulfill this standard two years earlier.

Similar approaches can be stated on city level towards *smart-city* and *smart-grid* concepts as well as *sustainable life-style* concepts and *low carbon economies*, attending the urgent need to change of our society.

Living Labs in Architecture do have the potential to foster learning and innovation processes as well as create open-innovation platforms for inter- and transdisciplinary research within schools of architecture. They may contribute efficiently to knowledge generation and innovation in the mentioned areas as well as they could be efficient tools to generate new competencies necessary for this purpose amongst the participating stake holders.

User-centered innovation, co-creation and collaborative learning are the main aspects of a large number of methodologies and tools that constitute current *Living Lab* concepts.

In the field of architecture, generated results can help to innovate in building concepts, materials and systems, improve energy efficiency more quickly, as well as allow the development towards more holistic sustainability concepts on city level.

Another important aspect is the development and exemplification of a more sustainable life-style which can be developed, analyzed and communicated much more efficiently within the real-life environment of *Living Labs*. These *living* laboratories allow an experienced-based learning process for its users and an immediate user feedback on innovations at product, system or concept level for researchers, developers and companies.

Living Labs within schools of architecture therefore have a great potential to be holistic tools for innovation, education, research and change of society in general. Due to their complexity and the novelty of the concept, view examples and experiences exist so far and further research on concepts and methodologies is needed.

2. Teaching sustainability

The pressure on environment produced by our industrial society on a global scale causes significant socio-environmental conflicts due to the limitation of resources, the environmental risks related to technology and the overall unsustainablity of the current socio-economic model based on continues growth.
Lobera (2010) describes the necessity of active participation or *active sustainability* of citizenry to solve socio-environmental conflicts, due to the"rising uncertainty and complexity of the interactions between techno-science, society and environment".

As a result new skills are necessary like the capacity of contextual thinking of technology on a local and global scale, the self motivation for learning, seen as a process with a high level of autonomy, and communication skills which allow knowledge sharing, discussion and debate. Embedded in a transdisciplinary context all these skills are essential for an understanding of sustainability and a positive transformation of socio-environmental conflicts based on teaching-learning processes. (Lobera 2010)

2.1 New skills and opportunities for architects

Parallel to these fast changing socio-environmental socio-economic scenarios we observed in the last decades a constant decline of the architect's role in our society due to specialization and concentration processes within the building sector, the change towards development processes dominated by real estate developers and engineering companies and a general loss of importance and clear definition of competences within the professional and social context.

The necessity for a holistic view on today's complex socio-economic and environmental conflicts and their possible solutions are a great opportunity for re-inventing and re-enforcing the role of architects as key persons within these complex social, political and economical processes. With a broad knowledge in different disciplines, advanced communication skills as well as detailed technical expertise, architects could evolve as promoters, mediators and experts within the transformation processes towards more sustainable architecture and urbanism within a more sustainable society.

2.2 New competences within the European Higher Education Area (EHEA)

Many of the core competences necessary for this new professional qualities and qualification for architects are already defined in a more general manner on a European level. The implementation of the common European Higher Education Area (EHEA) in 2010 not only introduces the possibility of more mobility within Europe for students through the European Credit Transfer System (ECTS) and facilitates the validation of degrees at universities within the EHEA, but especially defines a whole range of competences to be achieved through higher education, redefining the assessment processes, and looking for higher standards for teaching and research activities.

Inter and transdiciplinarity is one of the core competences for a holistic understanding and communication between different areas of knowledge, fostering a systemic view of complex socio-economic and environmental problems. Other important competences are critical thinking, decision-making, problem solving, leadership, autonomous learning, time management, information management and communication skills amongst others.

All these competences shall be fostered through a continuous and independent learning process guided by lecturers with a more active and participative role of students through seminars, reduced group lectures, debates and oral presentations as well as active participation in group works, projects and problem-based learning.

In the field of academic evaluation not only final exam results are important, but the overall learning process outcome in form of acquired knowledge and abilities taking into account projects, personal study, seminars, group works among others, focused on the holistic generation of competences and not only fragments of specific knowledge.
All these desired competences need new tools and methods to be introduced into higher education processes, especially to encourage students to participate actively and identify and define their own learning objectives at an early stage of their academic life.

2.3 Education in architecture

Education at schools of architecture must integrate and foster the mentioned competences among students through new learning methodologies, tools and concepts.
On the other hand a newly strengthened social responsibility of university towards society in the development of innovative solutions for our environmental, social and economic conflicts must lead towards new processes in teaching, research and technology transfer based on a strong interaction with local community and society in general.

Learning processes for architects are traditionally linked to real projects analysis as well as real life experience through visits and the direct perception of materiality, space, light and function of architecture, urban and landscape projects.
These same attitudes need to be introduced into the everyday learning activities with a especial focus on new urgent fields of knowledge like low energy buildings, renewable energies, environmentally responsible

materials, systems and concepts, and sustainable architecture, urbanism and life style in general.

On the other side knowledge, skills and abilities, generated and transmitted within the context of academia must be defined in a continuous process of critical reflection of real world problems and scientific and technological advances.
Within this context *laboratories* are already established as places of teaching and research on materials, construction technologies, as well as specific aspects like light, HVAC, building simulation or modeling and representation, with a link between theoretical knowledge and experiment.

As one step further real life environments like *Living Labs* integrate user-centered research and teaching concepts as basis for a realistic and holistic learning and innovation approach with a direct relation to society and its socio-economic and socio-environmental conflicts, and therefore might play a mayor role in the field of education in architecture in the future.

3. Living Labs

The term *Living Lab* is used recently to describe a research environment where "users are involved in the innovation process by designing, developing and validating new technologies, products and services with users in real life environments" (Almirall, Wareham 2008).

A *Living Lab* process is based on the activity of a multidisciplinary team in the following main activities (Pallot M. *et al*., 2010):

- ***Co-creation:*** *bring together technology push and application pull (i.e. crowd sourcing, crowd casting) into a diversity of views, constraints and knowledge sharing that sustains the ideation of new scenarios, concepts and related artifacts.*
- ***Exploration:*** *engage all stakeholders, especially user communities, at the earlier stage of the co-creation process for discovering emerging scenarios, usages and behaviors through live scenarios in real or virtual environments (e.g. virtual reality, augmented reality, mixed reality).*
- ***Experimentation:*** *implement the proper level of technological artifacts to experience live scenarios with a large number of users while collecting data which will be analyzed in their context during the evaluation activity.*
- ***Evaluation:*** *assess new ideas and innovative concepts as well as related technological artifacts in real life situations through various dimensions such as socio-ergonomic, socio-cognitive and socio-economic aspects; make observations on the potentiality of a viral adoption of new concepts and related technological artifacts through a confrontation with users' value models.* (Pallot M. *et al*., 2010)

Currently several *Living Lab* Networks are established with a total number of approximately 100 *Living Labs* worldwide. A large number of Living Labs have been developed in the field of information and communication technology.
Only a limited number is so fare focused on architecture like e.g. the PlaceLab (MIT) the ExperienceLab (Philips Research) or the Living Lab Project.

The European Network of *Living Labs* (ENoLL) is at present one of the main *Living Lab* networks, giving support to the development of Living Lab initiatives, attending the necessity to explore suitable processes and methods for user co-creation as well as organizing *Living Lab* workshops and other networking activities to further explore *Living Lab* practices and concepts with a clear perspective for a growing platform of methods within the next years. (Feuerstein *et al.,* 2008)

In the context of the international SOLAR DECATHLON competitions, held since 2002 in the United States and also in Europe since 2010 on a biannual basis, many energy-self-sufficient solar houses have been carried out by universities all over the world with the potential to be used as laboratories at the campus for research and innovation or even get one step ahead, becoming *Living Labs* in architecture. The Living Lab Low3 project is one of them.

Nevertheless, there is no clear definition of a *Living Lab* in architecture, its methodologies, instruments, and management so far due to their complexity and the large number of stakeholders, as well as their logistic and economic challenges.

4. Teaching and research activities CISOL (2003 – 2010)

The *Living Lab* LOW3 project must be understood as the last step in a 10 years development towards a more interactive teaching model in solar architecture at our school, based on the teaching and research activities of the Solar Research Centre (CISOL) at the ETSAV, towards action research and participative learning programs.
From 2003 on, a whole range of teaching formats have been introduced and established. Every new format intended to increase participation of students through self-organization and enrollment in pluridisciplinarity towards a holistic and dynamic learning process, linked more and more to applied research and innovation in the field of sustainability. *Living Lab* LOW3 is currently the most advanced step within this process.

4.1 Traditional teaching format: Design Workshops - TAP (2003-2007)

In regular design workshops, aspects of solar architecture, energy efficiency and renewable energies have been introduced to second year students through theoretical classes and design review. Materials and technologies have been presented through presentations and samples. Interactivity and participation are limited to traditional presentations and discussions about student projects within the classroom enriched through traditional case studies. Debate and participation as well as group dynamics are difficult to establish, large groups and limited time for discussion and knowledge generation are additional limitations.

4.2 Intensive workshop format: CISOL Solar Workshops (2005-2010)

CISOL Solar Workshops are 10-day full time workshops on solar architecture with a special focus on building integration of solar technologies and the bioclimatic optimization of buildings within an integrated energy design.
Special international guest lecturers have been invited to situate the workshop and its contents within a European context.

Fig.1: CISOL Solar Workshop 2009 – 10 day- full time workshop with international guest lecturer Bill Dunster, Londres

The participation in international competitions and the collaboration with companies from the solar energy sector improved the learning process for students significantly.
Some of the most interesting realized workshops programs have been the following:

- ISES solar housing competition for china (2007), special guest lecturer: Werner Lang, Munich
- Low energy student residence at the campus Sant Cugat (2008) special guest lecturer: Georg W. Reinberg, Viena
- Solar Decathlon Europe 2010 competition (2009), special guest lecturer: Bill Dunster, Londres

A number of 30-40 students with participation of Master students and a considerable number of international guest students allowed an intensive group dynamic and a collaborative learning process as well as an enriching interaction between students of different levels, backgrounds and disciplines.

All workshop projects where linked to real projects or competitions, fostered group working, transdisciplinary approaches and a holistic energy design for buildings.

4.3. Active learning modules: CISOL Research Afternoons (2007-2008)

Under the concept of "research afternoons" at CISOL 4 modules (solar technologies, bioclimatic architecture, materials and life cycle and sustainable urbanism) have been realized in 2007 and 2008, to introduce students in small-scale research about sustainability issues in architecture and urban planning. Small groups of 6-10 students worked on the subjects within the facilities of CISOL, including debates with other researchers, with the aim to relate results directly to current design studio projects of the students, applying newly generated knowledge immediately.

Fig.2 and 3: Research Afternoons at CISOL – debating and researching on sustainability in small groups

The modularity of the teaching format and the small number of students per module allowed lively discussions and personal involvement of students in researching and presentation of found results as well as the creation of learning outcome documents for all group members.
Competences like critical thinking, communication skills, systemic and holistic thinking as well as self organized learning were strengthened with a focus on sustainability issues at all scales.

4.4. Project based teaching: The Solar Cube project (2008)

The Solar Cube is an experimental module on PV integration in buildings. The project shows different PV technologies as façade and roof materials integrated in the building skin of the laboratory.
The module is energy self sufficient through a battery storage system. Energy efficient lighting, an exposition of PV cells and materials, and low energy appliances form part of this educating unit for students.

Fig.4, 5 and 6: SOLAR CUBE – Laboratory on Building Integrated Photovoltaic (BIPV) build by students

Mounted on wheels, its orientation can be changed for experimentation. In collaboration with industry, innovative PV panels have been developed and tested on their thermal and electric performance as integrated building elements.
10 Students collaborated in the design, construction and monitoring activities of the SOLAR CUBE during one year. Engineering students and companies collaborated with architects in its design and execution.

Teaching activities were linked directly to research purposes demanding a high level of responsibility, organizational skills, decision-making and transdisciplinarity.

The applied technologies and prototype materials formed part of real projects realized by CISOL in collaboration with public or private partners. Students collaborated in the corresponding design and evaluation activities, gaining valuable work experience in the field of solar technologies and building integration.
Generic competences like decision-making, leadership, planning and coordination, as well as interdisciplinary teamwork get fostered through this kind of project related teaching, with an intensive knowledge creation in a specific field, e.g. solar technologies and their integration in buildings.

4.5 The Solar Decathlon Europe 2010 competition (2008-2010)

LOW3 (2008-2010), the Solar Decathlon Europe 2010 Solar House of the UPC has demonstrated the importance and the impact of a new way of education in architecture, based on the development and construction of a prototype house with a high degree of team self-organization and a strong link between teaching and research.

More than 100 students participated in the project during 2 years, 50 team members constructed, operated and presented the prototype at the competition at June 2010 in Madrid with a strong implication of Master students and a multidisciplinary collaboration between architects and engineers.

Fig.7 and 8: Team UPC - Solar Decathlon Europe 2010 - prototype construction in Madrid, June 2010

More than 50 companies collaborated in its development allowing the exploration of innovative concepts for energy efficiency and installations as well as housing typology and construction techniques.

Students had to assume high responsibility and implication during the different phases of the 2 years project, developing transversal skills like working in a complex pluridisciplinary team, conflict solving and decision-making as well as communication skills towards collaborating entities and society in general.

Fig.9: General view LOW3

Fig. 10: LOW3 team at Madrid competition 2010

A total of 3 different “generations” of students participated between 2008 and 2010, from the design stage until construction, competition and exposition in Madrid in June 2010, learning continuously about sustainable architecture within an international multicultural context.

Low3 currently gets evaluated through a program of monitoring of its energy performance with a special focus on its bioclimatic behavior under summer conditions, giving feedback to the parallel thermal dynamic simulation.

All achieved results get introduced into the new Solar Decathon Europe 2012 project, currently under design. The project named (E)Co reflects a whole range of concepts of LOW3, developing them further and optimizing aspects like bioclimatic performance, energy consumption and a low cost concept.

5. Living Lab Learning Platform: Living Lab LOW3 (2010-2012)

In a second step (2010-2012) LOW3 will be implemented as *Living Lab* LOW3 – *Laboratory for sustainable architecture, energy efficiency and renewable energies* at the *Campus Sant Cugat* (Barcelona) with the aim to create a platform for innovation with a strong link to companies and a holistic concept for teaching, research and innovation activities.

Fig. 11: LOW3 as *Living Lab* at UPC-Barcelona Tech

Fig. 12: Concept of *Living Lab LOW3* at UPC

5.1 Academic format

Living Lab LOW3 adds value to the academic offer of UPC-Barcelona Tech and creates links between the traditionally separated activities of teaching and research through an innovative educational programme and the creation of a platform which links university with industry and research entities.

The ultimate aim is the design of innovative transdisciplinary educational programmes with active participation of industry and other innovation agents towards a holistic approach or *Integrated Energy Design* in Architecture.

A strong concept for user-centered activities is under development, involving academia, companies and research entities but also local administration, understanding students and academic staff as well as citizens as "users" of this newly generated platform.

5.2 Link to international education and research programs

International networks are essential for interchange and collaboration in higher education.
The *Living Lab* LOW3 project is already linked to the European Intelligent Energy programme through its participation in the 10Action programme, coordinated by *IDAE* and *UPM*, focused on the use of the Solar Decathlon 2010 prototype solar houses as educational tools for the general public.

Fig.13: Prototype construction Campus Sant Cugat March 2011 **Fig.14: Prototype evaluation meeting June 2011**

The second linked research activity is the participation in the KIC INNOENERGY programme which fosters research and teaching activities in the field of renewable energies and energy efficiency in buildings on a European level through a network of participating universities and companies. Through the *Co-location Centre Iberia* at *UPC*, *Living Lab* LOW3 participates with a first co-financed *Learning Module* focused on the development and implementation of LOW3 as *Living Lab* at the *Campus Sant Cugat.* The international perspective especially within the European context is essential for state of the art activities and innovation.

5.3 Link to local community and private enterprises

On a local level first contacts have been established for the involvement of local administration (Sant Cugat) for collaboration in education in sustainability, opening up the access to the citizenship of this municipality as another group of "users" of *Living Lab* LOW3 beyond academia and industry. From guided, formative visits to workshops on sustainability up to product co-design and user feedback evaluation on sustainable design solutions a whole range of tools and strategies wait to be explored within the Living Lab concept. First Living Lab activities and evaluation has already started (Figure 15 and 16)

Fig. 15: Living Lab LOW3 teaching activity **Fig.16: Living Lab LOW3 platform activity**

Private companies have specific necessities in the field of product and system development, as well as education and marketing in the field of sustainable architecture and energy efficiency.
Common interest have to be identified and projects have to be designed according to the particular interest of all public and private stakeholders.

5.4. Virtual platforms and web 2.0

At UPC level *Living Lab* LOW3 received funding through the *Improvement of Teaching program* and forms part of the *Atenea Lab* innovation programme, which opens up the possibility of a virtual learning platform creation, e-collaborations or virtual community activities, linked to LOW3.
Living Labs and their corresponding real and virtual networks have a great potential to activate students, researchers or citizens as users to form part of a co-creation community bringing together needs, ideas and solutions for new products, services and systems.

6. Comparison between teaching formats

Table 1 shows a comparison between the different presented teaching formats (see chapter 4) introduced at UPC-Barcelona Tech and their estimated impact on generic and specific competences, the generation of knowledge and abilities as well as the tools and methods applied and additional qualities identified in relation to a holistic learning process in sustainability in the field of architecture.

All evaluations are based on a subjective analysis and judgment by the author of the realized teaching formats and is therefore experience based and limited within a personal teaching experience.

Nevertheless the table allows analyzing to a certain limit the impact of each teaching format in the generation of competences, knowledge and skills in the field of solar architecture.

Tab. 1: Relation between teaching formats and corresponding competences, knowledge, abilities, tools and methods applied, based on the experience of teaching solar architecture at ETSAV – Barcelona Tech

	Teaching Format				
	Traditional Teaching Format Design Workshop	Intensive Workshop Format CISOL Solar Workshops	Active Learning Modules CISOL Research Afternoons	Project based Teaching Solar Cube Project	Living Lab Learning Platform Living Lab Low3
Generic Competences					
Critical thinking	++	++	+++	++	++
Decision making	++	++	++	+++	+++
Problem solving	++	++	+++	+++	+++
Leadership	+	++	++	+++	+++
Oral communication	++	++	+++	++	++
Autonomous learning	++	++	+++	++	+++
Use of new technology	+	+	+++	+++	+++
Time management	+	++	++	+++	++
Information management	+	++	+++	+++	+++
Capacity of work	+	++	++	+++	+++
Planning and coordination	+	+	++	+++	+++
Specific Competences					
History and theory knowledge	+	+	+	+	+
Social science and cultural awareness	++	+	++	+	++
Design skills	++	++	+	++	++
Technical knowledge	++	++	++	++	+++
Ethical and social commitment	+	+	+	+	+
Systemic and holistic thinking	+	++	+++	++	+++
Environmental responsibility	+	+	+++	+++	+++
Interdisciplinary teamwork	0	++	+	+++	+++
Project management	0	0	0	++	+++
Research and knowledge creation	0	+	++	++	+++
Communication and mediation skills	+	++	++	++	++
Knowledge and Abilities					
Holistic sustainable design	+	++	++	+	+++
Bioclimatic/ low energy architecture	+	+	++	+	+++
Energy Efficiency	+	+	++	++	+++
Environmental impact evaluation	+	+	++	+	+++
Life cycle analysis	0	+	++	0	+++
Energy and confort calculations	+	+	+	++	+++
Thermal dynamic simulation	0	++	0	0	+++
Renewable energy systems	+	++	++	+++	+++
Sustainable Urbanism	+	+	++	0	+
Sustainable Life Style	0	0	+	0	++
Sustainable Mobility and Transport	0	0	+	0	+
Tools and Methods					
Individual study planning	0	+	++	+++	+++
Group works-colaborative learning	+	++	++	+++	+++
Case studies	+	+	++	++	+++
Real projects	0	0	0	++	+++
Problem-based learning	+	+	+	++	+++
Web-based learning	+	+	++	++	++
Additional Qualities					
Relation to local community	0	0	0	+	++
Life long learning concept	0	0	0	+	++
Public-private partnership	0	0	0	++	+++
Combined teaching and research	+	+	+	++	+++
Innovation oriented activity	0	+	+	++	+++
Co-creation platform	0	+	+	++	+++

0 not significant   + partially significant   ++ significant   +++ very significant

It shows that a *Living Lab* Learning Platform offers the most integrative form of education for architecture students, covering almost all identified aspects necessary for a holistic learning process.

Nevertheless, a *Living Lab* approach needs special efforts and means in terms of teaching staff, economic resources, complexity of multiple collaborations on public and private level as well as a specific motivation of students for a self-organized learning schedule, responsibility and self motivation as well as problem solving and working in a complex group environment. Especially these skills and abilities and competences are identified as essential within the EHEA towards a more transdisciplinary and innovation oriented learning process at universities.

Regarding specific knowledge, abilities and skills in the field of sustainable architecture *Living Lab* LOW3 is a learning format, which allows a high level of learning through real experience of design, construction, installation and monitoring of a prototype solar house. This offers a unique experience to students in all important subjects like bioclimatic architecture, solar technologies, environmental friendly materials and systems, as well as low energy HCVAC systems.

Additional qualities generated through *Living Labs* are related to its function as co-creation platform, linking teaching, research and innovation activities with multiple stakeholders implicated through public-private partnerships with a special focus on local communities as well as innovation oriented companies.

The complexity of this format exceeds that of standard teaching like lectures or workshops and therefore requires additional efforts, means and motivation. Nevertheless it provides a unique and holistic learning experience.

7. Methodology and evaluation of *Living Lab* LOW3

The implementation of *Living Lab* LOW3 at the *Campus Sant Cugat* is a dynamic process, based on the same co-creation process which is one of the basic principles of all *Living Labs*. Throughout the 2011 and 2012 teaching activities, public-private partnerships and user co-creation activities will be developed step by step.

Main research areas will be net zero energy buildings, renewable energy systems in buildings and sustainable architecture and lifestyle in general.

Goal will be a focus on experience research within the academic framework of a school of architecture, with an emphasis on measuring real-life use of products, systems and concept related to sustainability in housing, taking in consideration that a *Living Lab* is not only a infrastructure but a network of real people with rich experiences with a great importance of the human factor between all participants and users. (Mulder *et al*., 2008)

A continuous process of documentation of the development process of LOW3 on its way to become a *Living Lab* will be one important way for the analysis of its concepts and mechanisms.

From its start as an international competition of schools of architecture (2008-2010) until its full operation as *Living Lab* LOW3 in 2012 at the *ETSAV* school of architecture a multi-level documentation will allow to describe the process on a individual / team level, on a project / school of architecture level, on a university / institutional level, and on a society / context level.

One important issue within this ongoing research is the evaluation of impact of the developed *Living Lab* concept. The development of the right indicators as well as the evaluation of the acquired skills and competences by the *Living Lab* users, the evolution of the *Living Lab* process as well as the critical analysis of the achieved results will be an important outcome.

Regular evaluation of impact will be done by interviews with students and other participants of the project as well as questionnaires about the evolution of the project, threats and opportunities, strengths and weakness of each stage and activity.

At the same time a systematic analysis of other *Living Lab* projects will allow learning from existing projects, developing a special concept for LOW3 as *Living Lab* in architecture. Contacts will be established with other *Living Lab* developers on national and international level.

Especially the strong link to other existing Solar Decathlon projects and an active participation in the ENoLL *Living Lab* network will allow a comparison of different Living Lab concepts and their evolution over the last years as well as establishing collaborations with similar projects.

8. Conclusions

Living Labs are complex infrastructures for research and innovation and have the potential to be emerging tools for teaching, linking all three activities within a creative real life environment based on user co-creation and open innovation.

Today *Living Labs* are not based on common tools and proceedings as every approach depends on individual objectives, resources, stakeholders and interests as well as the type and availability of specific user groups.

Methodologies need to be developed for managing complexity and especially user participation and evaluation of results. Clear objectives as well as workflows, necessary stakeholders and resources have to be identified clearly and finally activities have to be integrated into academic curricula and the academic schedule with its specific division in semesters and academic years at university.

Especially the combination of real life *Living Labs* with virtual user platforms creates an enormous potential for co-creation processes and collaborative activities.

Living Lab LOW3 is a first attempt to integrate a *Living Lab* concept into the research and teaching environment of the Vallès School of Architecture at UPC-Barcelona Tech. Its implementation and gradual growth will generate valuable experience for further search of innovative teaching methods, with a strong link to research and innovation in the important field of sustainable architecture and sustainable development of our society in general.

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