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SUSTAINABLE DESIGN STRATEGIES AND TECHNOLOGIES FOR A GREEN SPACE FOR STUDENTS AT TERRACINI CAMPUS, UNIBO

Sara Rizzo[1*], Francesca Cappellaro[1,2], José Ramòn Ruiz-Checa[3], Valentina Cristini[3]

[1]*DICAM Department of Civil, Chemical, Environmental, and Materials Engineering. University of Bologna, 28 via Terracini, 40138, Bologna Italy*
[2]*ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development, UTVALAMB-LCA*
[3]*Heritage Conservation Institute, Polytechnic University Valencia, Spain*

Abstract

To make sustainability transitions happen, it is crucial not only to have strategic planning processes committed by the top management, but also to encourage community engagement, approaching and promoting a bottom-up process. In the specific case of a University Campus, that means the involvement of the students not only as consumers, but with a leading role in the sustainability process. DICAM department of University of Bologna has recently started the implementation of some practical actions to create a sustainability campus Terracini. These activities are parts of the Sustainability Plan of Unibo. A multifunction group, called Terracini Transition Team is managing some of these actions located in Terracini Campus. Moreover, a new model of pedagogy, called flipped classroom, has been experimented. Therefore, Terracini Transition Team has been proposing an innovative and engaging idea that could support sustainability measures: the realization of a space for students designed by themselves with an inclusive and participative approach. To meet environmental performances, the space will be planned with the use of appropriate building technologies, employing low impact and local materials. In addition, the space will be realized in auto-construction, in order to strengthen the involvement of final users, the students. This paper will show an evaluation of appropriate building technologies with an LCA approach. Finally, the reported LCA case-studies has provided the robustness to drive the choices of low impact solutions for the sustainability of Unibo. Finally, the paper demonstrates the efficacy of the adoption of whole-system approach integrating experiential learning with sustainability assessment.

Key words: appropriate technologies, experiential learning, LCA, sustainability transition, sustainability campus

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1. Introduction

Although a high number of international initiatives are promoting campus sustainability (Calder and Clugston, 2003; Wright, 2004), Sustainable Development, SD, still endeavours to become integral part of the whole university system (Bekessy et al., 2007; Lozano et al., 2013; Thaman, 2002). There is the need to overcome the current fragmented approach to SD (Burke, 2000; Cortese, 2003), the adoption of whole-system approach and the creation of proactive processes help to integrate the theory and the practice of sustainability within the campus in order to reconnect education, research and campus operations (Koester et al., 2006; Sharp, 2002). According to UNEP (2013), in this framework, a crucial issue can be played by the students' engagement as co-creators of knowledge, agents and drivers of change (Müller-Christ et al., 2014). According to Kolb (1984), "learning is the process whereby knowledge is created through the transformation of experience". Therefore, the

* Author to whom all correspondence should be addressed: e-mail: sararizzzo@gmail.com; Phone: +39 3495648721

learning process can become an experiential learning process by the use of “real world” problems as the context for students to learn critical thinking and problem-solving skills (Bould and Felletti, 1991; Hansman, 2001).

This paper presents the flipped classroom (Foertsch et al., 2002; Lage et al., 2000) as an experiential learning process for sustainability that develop opportunities to teach the theory and the practice of sustainability. The result could be the transformation of the campus into a living-lab of sustainability. In the academic literature, there are numerous examples of the concepts of living-lab of sustainability (UNEP, 2013). Particularly, the case of the Engineering and Architecture School of Bologna University represents a successful case of how to transform campus into a living-lab of sustainability (Cappellaro and Bonoli, 2014). Driven by an experiential learning approach, the Terracini initiative is aimed not only to improve the campus sustainability but also to raise the environmental awareness of the whole university community and especially of Engineering students.

The main instruments adopted for this process are environmental assessment (LCA) and pedagogical methology called Flipped Classroom. This paper presents the realization of a space for students as an innovative and engaging idea that could help to enhance the sustainability process ongoing at Terracini Campus through practical functions of teaching and research with a direct involvement of students. This space can be a driver for enhancing an inclusive and participative approach and provides a significant opportunity to put into practice sustainability concepts. The project will include the sustainability goals in all the life-cycle phases of the students’ space realization. Since the design phase, a Life Cycle Assessment study supports the selection of appropriate building technologies with the aim to employ low impact and local materials (Ciutina et al., 2010; Simion et al., 2013; Tundrea et al., 2014; Zhang et al., 2014). Then, the manufacturing phase is meant to realize the space in auto-construction. In this way, the involvement of final users, the students, is constructively strengthened. Furthermore, the use phase is planned to assure energy efficiency target and zero waste and consumptions.

The final aim of this paper is to demonstrate how the adoption of sustainability as whole-system approach can contribute to make sustainability an integral part of the university system. Definitely, the transformation of the campus into place of sustainability can help society to become more sustainable.

2. Materials and methods

2.1. Method and project structure

For the development of the experience in Terracini Campus (Bonoli and Cappellaro, 2013), as a working basis we propose the methodology and results obtained thanks to a recent research project of sustainability, VERSUS “Lesson from Vernacular Heritage to Sustainable Architecture” (Correia et al., 2012, 2014). This way, students propose a project evaluated following the sustainability criteria set by the VERSUS project, in which some authors of this text are directly involved, as following explained. During each classroom session, a rigorous and detailed analysis of the project is carried out from different approaches. Thus, each session is aimed at each of the 15 principles derived from the VERSUS project (Mileto et al., 2015a, 2015b). These principles, in turn, are grouped into three different scopes, so that students are aware of which scope they are working in at all times:

- **Environmental Scope** (5 principles): to respect nature, to be appropriately situated, to reduce pollution and waste materials, to contribute to health quality, to reduce natural hazards effects.
- **Socio-Cultural Scope** (5 principles): to protect cultural landscape, to transfer construction cultures, to enhance creativity, to recognize intangible values, to encourage social cohesion.
- **Socio-Economic Scope** (5 principles): to support autonomy, to promote local activities, to optimise construction efforts, to extend the building’s lifetime, to safe resources.

Prior to the session, students are presented with different resources and content (videos, links, examples, web applications) based on principles that are to be treated. Once a classroom session has started, the teaching model follows the following timetable:

- **5 minutes:** Initial open appraisal of the previously proposed resources and content. This way the teacher is aware of the starting level of the students and can adjust the intensity of the session, or identify students with learning issues or deficiencies.
- **5 minutes:** Discussion on the results, so that the students can identify their deficiencies or learning issues.
- **10 minutes:** Questions raised during the previous stage are solved together. Thus, those questions resolved collectively can reach the entire classroom.
- **15 minutes:** Once students have worked on the assignment (apply, understand, remember - Bloom’s taxonomy), the next step is for them to create, evaluate and analyse (Bloom’s taxonomy) their proposals from any of the aforementioned principles of sustainability.
- **10 minutes:** Joint discussion of the results of the various assignments, and selection of the best approach for the project.
- **10 minutes:** The teacher engages the students in different games, based on the principles discussed so far with the aim of consolidating what has been learned.

After the classroom sessions designed to create, to evaluate and to analyse the project proposal, we turn to the stage of erecting the building, a task carried out by the students themselves. The criteria are obtained by flipped classrooms, considering Versus Project support crossed with LCA analysis. In this frame, as following explained, straw and raw earth plaster applied on a straw bale wall are interesting techniques to be developed. The choice of straw and earth is compatible with auto-construction and low impact design, and assure good energy performances (Fugler and Gonzalez, 2002) and indoor comfort (Fugler, 2000). These solutions could suit socio/ cultural/economical scopes and perfectly adapt to local context of Terracini Campus, involved in "KM0" scenario.

2.2. Life Cycle Assessment of a straw and raw earth plaster

In order to assess the sustainability of a straw and raw earth plaster and identify the environmental hot spots of the system, a Life Cycle Assessment compliant with the ISO norms on LCA (ISO 14040, 2006; ISO 14044, 2006) has been performed. The assessment was carried out using a "from cradle to grave " approach considering as functional unit 1m^2 of plaster with a supposed life span of 100 years. The life cycle has been divided in 4 different phases (Fig. 2):

- the production phase of the plaster
- the installation phase
- the use phase
- the end of life phase (EOL)

The case study belongs to a real experiment located in Todi, Ist. Agrario Ciuffelli, planned by Arch. Eliana Baglioni in collaboration with PantaRei Experimental Center (PG-Italy)(Fig. 1).

Fig. 1. Straw and raw earth plaster applied on a straw bale wall

Several inspections at the construction site and interview to designers have allowed the data collection needed to perform the LCA of straw and raw earth plaster. When primary data have not been available, literature data and the Ecoinvent database have been used.

In the construction of the production and use phase, the extraction and production of all the raw material used have been accounted. Moreover all the transports needed to move the raw material to the construction site and the energy consumed have been inventoried in this phase. In addition, an industrialized production, installation and use of the plaster have been constructed, in order to become more relevant the comparison between a straw and earth plaster with a cement and lime plaster.

For this reason, the use of additional installation has been considered, such as electric sieve and cement mixer. The inventory could be parameterized so that the LCA can be replied for different surfaces in terms of area and plasters.

2.3. Sensitivity analysis

In order to deeply investigate the environmental impact of a straw and earth plaster, a sensitivity analysis, in terms of materials transportation, end of life scenarios and comparison with a conventional cement plaster, has been carried out.

2.3.1. Materials transportation

Different scenarios in terms of materials transportation have been investigated. The first one is based on the hypothesis that the construction materials come from distant locations, as described in Table 1. The case that the raw materials (straw and earth) have been collected very close to the construction site is investigated in the second scenario, called "KM0". This is compatible with the real case (Table 2).

Table 1. Transport for straw and raw earth plaster

Straw and raw earth Plaster	
Component	***Transport from production site to building site (km)***
Earth barbottina	200
Earth 1° layer	200
Earth 2° layer	200
Straw 1° layer	70
Sand 2° layer	200
Sand and lime 3° layer	200

2.3.2. End of Life scenarios

Different end of life scenarios have been studied. The process belongs to the Ecoinvent database, with some modifications, as illustrated in Table 3.

2.3.3. LCA of a cement and lime plaster

A sensibility analysis has been carried out confronting the LCA of the straw and raw earth plaster with cement and lime plaster.

The data of the composition of the cement and lime plaster become from the Pescomaggiore straw bale houses (Bonoli et al., 2014).

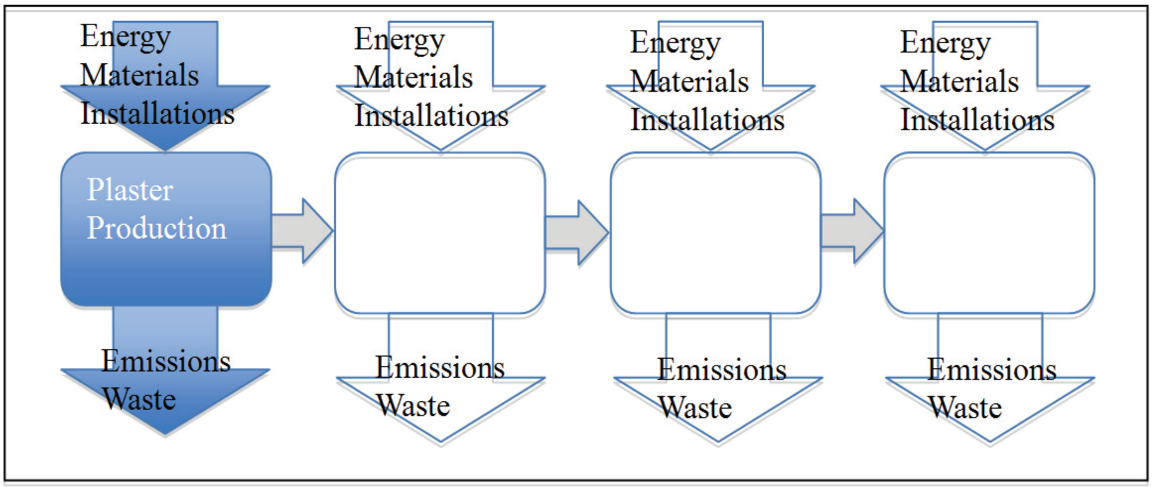

Fig. 2. Process flow chart

Table 2. Transport for straw and raw earth plaster – km0

Straw and raw earth Plaster – km0 case	
Component	***Transport from production site to building site (km)***
Earth barbottina	1
Earth 1° layer	1
Earth 2° layer	5
Straw 1° layer	1
Sand 2° layer	200
Sand and lime 3° layer	200

3. Results and discussion

3.1. LCA of a straw and raw earth plaster.

The use phase shows the highest damage (82.82%), overall due to the particulate emissions in atmosphere from the third layer of plaster in a period of time of 100 years, cause to the atmospheric degradation. A contribution to the damage comes from the emissions in atmosphere during the production of the layers for the maintenance (use phase). The damage is for the 90.41% in the Human Health, due to the emissions in atmosphere. Fig. 3 shows the characterization phase for the straw and raw earth plaster.

3.2. Comparison between straw and raw earth plaster, straw and raw earth plaster-km0 and cement and lime plaster

Fig. 4 the comparison between cement and lime plaster (left), straw and raw earth plaster and straw and raw earth plaster-km0 (right). Fig. 4 shows that the total damage of the cement and lime plaster is a 7.51% greater then the total damage of the straw and raw earth plaster. The damage in Climate Change and Resources is due to the production of cement and lime. The "km0" solution, as a consequence of a reduction of transports, can reduce the damage of a 7.63% less than the straw and raw earth plaster, and a 15.71% less than the cement and lime plaster.

3.3. Comparison between different end of life scenarios

Fig. 5 shows the different EOL scenarios: Incineration (left), Construction and Demolition Waste recycling, Disposal, 85% to Disposal and 15% to C&DW recycling, Restoration of a clay quarry (right). The process of incineration produces the greater damage. The process of restoration of a clay quarry, followed by the process of C&DW recycling, produces the lowest damage.

Table 3. EOL scenarios

EOL scenario	***Process from Ecoinvent***	***Notes***
Incineration	Disposal, building, cement-fibre slab, to final disposal/CH U	
Construction and Demolition Waste recycling	Disposal, building, cement-fibre slab, to recycling/CH U (with transport)	Transport from construction site to disposal has been considered
Disposal	Disposal, building, cement (in concrete) and mortar, to final disposal/CH U	
Disposal and recycling	Disposal, building, cement (in concrete) and mortar, to sorting plant/CH U	85% to Disposal, 15% to C&DW recycling
Restoration of a clay quarry	Fine vita intonaco di terra cruda (da Disposal, building, cement-fibre slab, to final disposal/CH U)	The straw and earth plaster is reused as filler for the restoration of a clay quarry

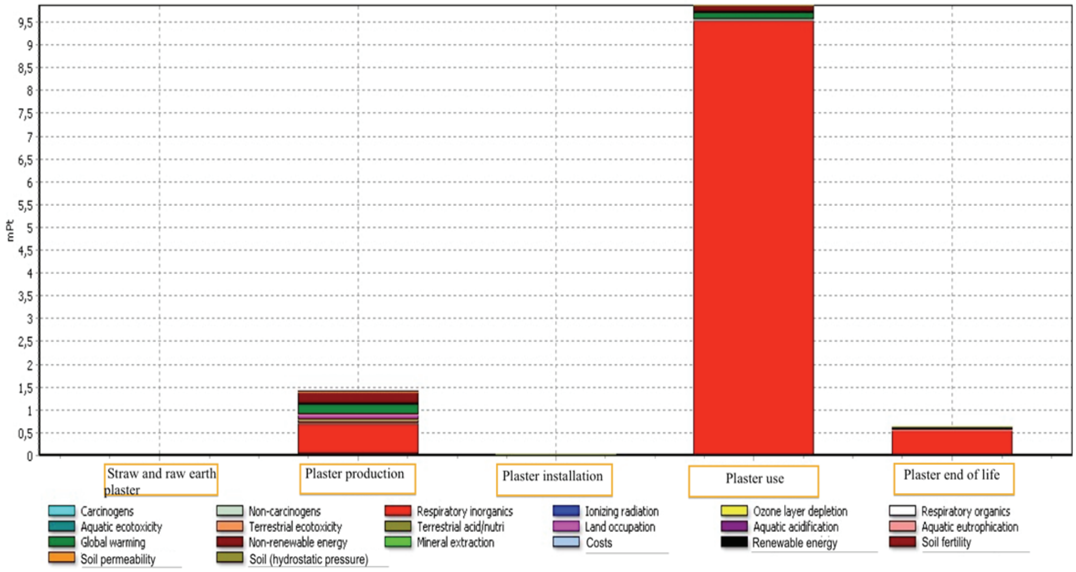

Fig. 3. Characterization phase for the straw and raw earth plaster

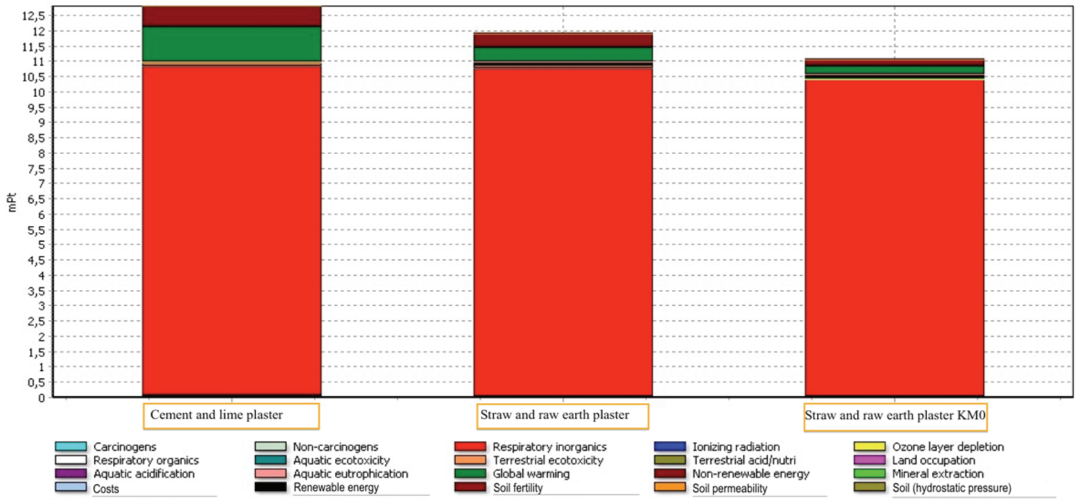

Fig. 4. Comparison between cement and lime plaster (left), straw and raw earth plaster and straw and raw earth plaster-km0 (right)

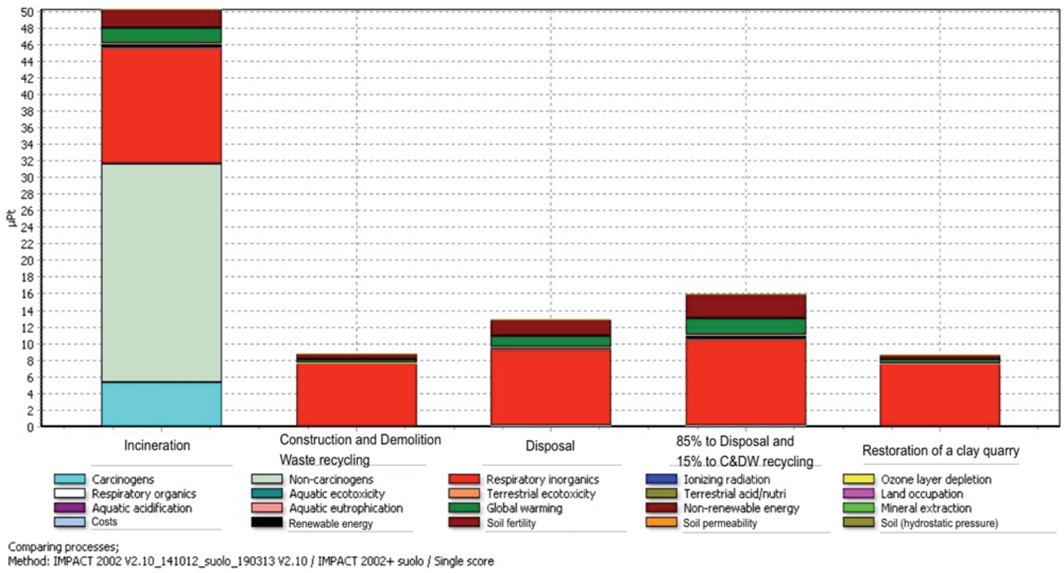

Fig. 5. Comparison between different EOL scenarios

4. Conclusions

The process follows interesting pedagogical steps, replacing the creation/evaluation/analysis stage with another, based on the execution of the auto-construction building at the Terracini Campus of the University of Bologna.

This construction could play an important role as the place where all the initiatives, activities, courses, lectures developed by the Transition Team of the University of Bologna will be centralised. In other words, from an initiative of innovative learning education emerges a space that serves to change the way of devising solutions related to the sustainability or the energy efficiency of the Alma Mater Studiorum Università di Bologna.

In order to assure an eco-design of this space, an LCA approach is fundamentally important, at the same time with the application of sustainable building technologies. These results confirm the choice made during the design phase and allow the students to strength their knowledge in the field of sustainability methodology. The results of the LCA can be useful to guide the realization of the space for students: it will be realized with km0 materials like straw and raw earth at least for plaster and infill wall; it will be designed for an end of life compatible with selective dismissing, so that the raw materials can return to nature; in the manufacturing phase the students will be involved, to improve their skills and sustainability awareness.

Thus, we propose a Transition case study involving both education and sustainability in our universities.

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