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Educating about sustainability in Cultural Heritage: an interdisciplinary approach

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Abstract. The text briefly traces the educational objectives and methodologies adopted in a highly specialized course (post-Master programme) which for years has trained specialists in the field of conservation and restoration of the architectural monumental heritage, with particular attention to the improvement of energy efficiency and to the inclusion of devices powered by renewable energy sources, while preserving the main role of education in architectural and material conservation. It is quite a 'pioneering' experience, compared to its frame of reference, based on the mutual consideration of different specialisms and on an interdisciplinary concept of the work (by sharing objectives and languages by experts in scientific sciences and human sciences implement their own methodologies to achieve a common purpose). Further increased with research opportunities at national and international level, these experiences have led to an awareness of the key players in the process of conservation, a high-level training of technical specialists and to some valuable experiences, currently underway.

Keywords – Conservation; Inter-disciplinary; Specialisation; Energy Efficiency; Cultural Heritage.

1. Introduction. The extension of the concept of heritage and the environmental challenges of contemporaneity

The built environment that surrounds us, bearer of cultural, architectural and landscape interests, of historical and social memory [1] is a precious legacy of the past. Both tangible and intangible evidence which feeds the cultural baggage of society is a valuable asset for our present and influences our way of thinking about our future. Each generation, therefore, implicitly or maybe unknowingly, bears the responsibility for the decision as to what to pass on to future generations, according to cultural trends of their own era [2]. The legacy of the past, especially when it comes to tangible Cultural Heritage, cannot therefore be ‘frozen’, but rather preserved by accepting its interpretation and changes. Indeed, heritage which is too detached from everyday life and from its needs is left without heirs, abandoned and neglected. On the contrary, its excessive transformations can irremediably change its historical, testimonial, tangible and economic values [3]. Compared to the last decades of the last century, the new millennium must also face challenges that have a lot to do with the concept of risk. Climate changes and their effects on stability, safety and comfort, sustainability, smart construction and domotics lead to reflections, methodologies, practices, policies and new languages of contemporary architecture also in the intervention on historical heritage [4].

Thanks to the growing economic value conferred to such heritage, nowadays the architectural culture traditionally linked to conservation is called to face new challenges: safety, accessibility for everybody, resource efficiency, comfort and savings in energy consumption, carbon and ecological footprint. All

this requires keeping professionalism constantly updated, able to set up and carry out feasibility studies, complex programmes and final projects suited to the needs of the sector.
How can cultural and technical skills capable of dealing with the complexity of these processes be developed? [5] How can conservation specialists be trained to be aware, responsible and at the same time open to the renewed needs of the community, balancing scientific and humanistic knowledge, innovation and tradition? [6] The problem is not confined within national borders; the European architectural culture, with particular reference to training and education, underlines also the pressing need to identify pedagogical methods suitable for the trans-disciplinary nature of designing, starting from a sound understanding of the discipline but able to go beyond single specialist knowledge [7].

2. The Frame of reference. A new stimulus to sustainability in the field of built heritage and emerging issues

At a national level, in response to the serious situation caused by the pandemic emergency, the introduction of state financial incentives, with considerable fiscal benefits, helps to accelerate and give new stimulus to specialized technical professionalism. These benefits are connected to the construction site with particular reference to the interventions on façades (conservation, recovery and restoration, an incentive promoted by the Ministry of Cultural Heritage and Activities and Tourism – MiBACT) and the so-called 'eco-bonus', a measure which grants special benefits for building interventions aimed at energy efficiency, the refurbishment of buildings and their anti-seismic compliance. The latter, in particular, lays bare the opportunities but also the 'conflicts' that emerge from its application to historical heritage, especially if it is of cultural and monumental interest.
It is precisely in this field that there are gaps in the training of technicians. On the one hand, there are experts in energy efficiency working in the field of new constructions or in the field of substantial refurbishments (in other words, those who have been trained and practise a profession mainly in the engineering field), although untrained to face the problems connected with the conservation of historical buildings. On the other hand, there are experts working in the field of conservation, with a long-established background of the discipline, known as 'humanistic' in the academic world, far from the problems, objectives, languages and methodologies employed to achieve significant improvements in comfort and energy saving. However, the Western culture is now permeated with the objectives of sustainability, saving of resources and environmental well-being and comfort [8] [9] [10]. Despite the strong connection between these principles and the conservation of architectural and material resources, the tension towards conservation of historic buildings with almost zero-energy or the use of renewable resources in projects for the conservation and reuse of historical monumental heritage, remains an achievement that is still very far from the sector of Cultural Heritage protection.
There are manifold reasons for this. There may be some lack of interest, at times even contemptuous, among the generation that contributed to developing the theoretical methodological debate and conservation processes which came into being after the War, towards the new challenges of contemporaneity [11]. There may also be some distrust towards experts in the energy sector, who are considered too far from the world of conservation (in sharing objectives, principles and sometimes even languages). There may also be a certain inability to read and share 'scientific' approaches. There may be reasons linked to methodological and technical incompatibility, inevitably bringing tangible conservation into conflict. This has created, at least in the second-level training course (master's degree), a lack of cohesiveness which requires to be urgently addressed in view of the demands of the professional world.

3. The experience of a Higher-Educational School (School of Specialisation): learning objectives and methodology

For some years now, the School of Specialisation in Architectural and Landscape Heritage has been working on these issues, anticipating the importance of sustainability objectives and ensuing working practices [12]. The School offers a two-year higher professional training course (third level training, based on the European Directive) (post-graduate programme), open to Master's degree graduates in the field of architecture, construction engineering, Cultural Heritage, archaeology, which gives access to a specialist qualification especially useful for the profession in the field of architectural heritage and

landscape protection. The School therefore tends to train professionals with a sound technical profile, with a wealth of skills and competences and, above all, aware of the many aspects and multiple cultural conflicts that characterize this delicate area of study and work.
The teaching methodology of the School aims at providing future specialists with the acquisition of the knowledge, skills and training required to carry out and manage the main and most common non-destructive analysis and diagnosis techniques on material consistency of existing architectural structures and their performance, also in terms of energy. In addition, the course will provide an in-depth analysis of the skills required to carry out and coordinate the various stages of the intervention on the built heritage. This will span from the preliminary to the final project, from the construction process, with the management of the works, up to the future of the restored cultural asset (scheduled maintenance and conservation, usage methods and management methods). Particular attention will be paid to the training areas, dedicated to digitization and the use of ICT (Information and Communication Technologies) in the intervention on cultural heritage (GIS and web-GIS for architectural complexes). For instance, data management is an essential step towards supporting the complex decision-making process of recovery operations, following the future life of the artefact, once recovered and reused in order to define its overall management.

4. Methodology of analysis and study. Intersections and interaction among different sciences
The delicate issue of energy efficiency in historical heritage represents a 'boundary line' or rather a delicate 'interstitial' space, because of its tight constraints, generally known to those working in the field of conservation: insulating a historic building on its external surface, even if without decorations, is - at list at national level - prohibited; modifying the thickness and shape of a roof to insert a layer of insulating material underneath the mantle is, again, prohibited; in some cases, replacing doors or windows with new and certified ones is prohibited; during the authorization process, the difficulty of integrating into the building (historic and listed) components powered by renewable sources of energy (photovoltaic panels on the roof or façade, for example) is evident. Yet, these constraints can be turned into design opportunities, since they encourage architectural research towards new solutions, bringing together innovation and conservation.
The improvement of the historical and architectural heritage, even in terms of energy-saving, therefore, represents a field of study and action which is difficult to classify according to the traditional disciplinary boundaries (albeit now questioned). Arguably, the best solution to the technical problem of efficiency may come from intersection of disciplines, from the results of thorough analysis, scientifically conducted, which question or re-question the dating of materials or construction components (plaster surfaces, walls…) and therefore their allocation into historical periods. The application of instrumental diagnostics, compared to archival analysis and interpretation of the sources of documents, allows the identification of the layout of ancient systems which can be recovered, avoiding useless and damaging new breakages in the traditional wall structures or cavities of different nature (for example to the impost block, at the intersection with the wall, often hollow or filled with detritus) to be used to insert low-density loose insulating materials, as well as for the passage of new installations (controlled mechanical ventilation).

5. Discussion. Sharing conservation aims
The study, research and intervention on the historical heritage, aimed also at energy improvement, allow us to broaden the disciplinary boundaries and to enhance the results of the respective analytical activities, not only by enriching the knowledge of the heritage asset in question, but also by modifying it according to the fundamental principles of conservation. Indeed, it is not the mere application of thorough and scientific analysis or the subjective interpretation of historical-artistic values with 'critical' approaches without shared protocols that matters.
What matters are the questions that the special technicians must ask themselves and the community in tackling a conservation, reuse and energy saving project for a historic building:

- How to identify the 'soft' parts, that is those that can be modified, replaced and/or integrated with heat flow and dispersion control techniques?
- How to reconcile conservation of matter, form, architectural spatiality with system innovation?

- How and where to insert devices powered by renewable energy sources?
- How to achieve sustainability objectives in order to respond to the demands of the technical regulations, possibly balancing the results obtainable from different interventions, rather than maximizing each of them?

Figure 1 The former University Library, in the space of the Jesuit's Collegium Church (in the middle, XVII C.). Actually abandoned, it is under analysis by the School for a complete renovation, restoration and reuse.

Figure 2 The Villa of Prince Andrea Doria (XVI C.). One of the aisles (actually partially abandoned) has been analysed and studied within the didactic program, designing new uses and energy efficiency solutions

Figure 3 The Ducal Palace in Genoa, inner courtyard (XVI-XVIII C.). The Loggia at the first floor has been closed to use it for temporary exhibitions.

Figure 4 The new design of the Loggia, recurring to high performance glass, allows to close the exhibition space without renouncing to its original visual permeability.

It would be easy to answer that each of these questions is, implicitly, an objective of the project and the answer is exclusively an heuristic one, according to the case and the person (designer) and to one's sensitivity and creativity. Indeed, these may be important skills but are insufficient.
Identifying the 'soft' parts of the interstitial spaces, of the territorial boundaries that more easily lend themselves to modification and technical innovation (e.g. use of insulating materials compatible with traditional materials without losing material culture evidence, replacement of glass panes with special 'vacuum' sheets while preserving the existing frames, inclusion of photovoltaic elements specially designed as outdoor furniture rather than panels resting on the roof surfaces), can only come from the intersection between different analysis (historical, archival, chemical), with their data, assessments, interpretations, predictions. This suggests that in cases of exceptional architectural value and material integrity, the only possible interventions are related to the method and type of management of the heritage asset. While distinguished by a strong professional orientation, the School of Genoa still acknowledges the research opportunities to be found in this new field. For this reason, the organization

of didactic activities follows the stages and the process of a real project of conservation, albeit over the two-year course. In the teaching activity, interdisciplinary laboratory is a priority, an opportunity to outline an analytical-diagnostic career path, under the supervision of a teacher, in the first year and with a strong design orientation in the second year. The Workshop (as an atelier) is carried out on a specific artefact and a specific site, chosen in agreement with the conservation bodies or other subjects on the territory, which they will restore in the future (Figures 1, 2, 3, 4, 5). By working on the selected artefact, the students therefore have the opportunity to carry out clearly oriented studies, followed by the development of a project based on the correct implementation of technical solutions, culturally aware of and consistent with the regulations in force, with the different and often contradictory need for protection, conservation, use, environmental sustainability, improvement of energy and seismic performance, enhancement and future management of the heritage asset.

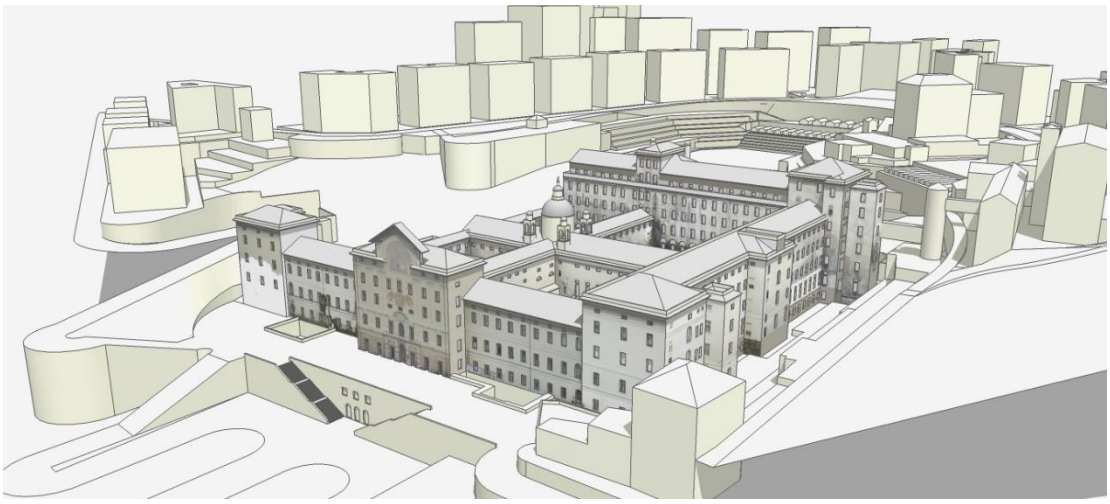

Figure 5 The *Albergo dei Poveri*, a huge monumental complex in Genoa (XVII-XIX C.) partially used as the humanistic pole of the University of Genoa and mostly abandoned (65% of the total surface). The School of Specialisation studied for several years its possible reuse recurring to renewable energy solutions and thermal insulation

Therefore, the first year of activity foresees the study of the building and of the site suggested by the teacher with the intertwining of thorough analytical methods and interpretative approaches on 'objective' data: morphological analysis (thorough direct, topographic, photogrammetric, laser scanner surveys, geometric checks and topology surveys, processing and analysis of digital images, computer modelling); chronological analysis and architectural archaeology (archival investigation and historical research, dating methods, archaeometry, stratigraphy, excavation techniques, all analytical-diagnostic activities equipped with recognized protocols); analysis of materials and construction techniques (chemical-physical tests, mineralogical-petrographic and mechanical cataloguing of materials, to hypothesize the dating, analysis of the phenomena of alteration and degradation of the material, of weaknesses and damage of the construction components and technological and hygienic-sanitary deficits); structural analysis (study of the structural conception and performance of traditional and modern building works, analysis of structural instability through non-destructive diagnostic techniques and on-site tests, consolidation techniques). During the first year, particular attention is paid to the use of information technology (ICT) for the cataloguing and management of the data acquired in the study phase (GIS environment).
On completion of the first year, the trainee acquires the following knowledge and develops the relevant skills:

- Understanding of the architectural artefact, through the study of its geometries, construction elements and materials, surfaces, structures, spaces and functions.

- Understanding of the transformations that the building has undergone over time, relating the findings of the historical reconstructions from indirect sources and those of direct archaeological analysis.
- Evaluation of the state of conservation of the building, as a whole and in its individual parts and construction components, recognizing decay, damage, weaknesses, deficits affecting materials, construction elements, systems and structures.
- Identification of the causes and extent of such damage, assessment of the vulnerability and level of exposure of the heritage asset to the aggression of environmental factors and related risks.
- Evaluation of the compatibility between the function and the current uses, the nature of the spaces available and the primary conservation needs.
- Management of sets of information of several kinds, complex, heterogeneous and in progress, through the construction and querying of relational databases and, in general, of digital data management systems.
- The definition of criteria and guidelines in order to plan the conservation, restoration and redevelopment interventions of buildings and spaces of cultural interest, thus identifying the 'interstitial' spaces in which it is easier to suggest modifications and 'grafting' of new technologies.

During the second year, with the elaboration of the restoration project on the building pertaining the activities of the first year, the following is studied and tested: structural consolidation (diagnosis, calculations, seismic improvement); interventions on constructive and technological components (masonry, wood, metal); interventions of technological, plant engineering, regulatory adaption and improvement of thermal-energy performance (energy diagnosis, calculation of thermal bridges, analysis of the consumption related to new uses, also with dynamic modelling software); practical restoration tests (sampling, on-site analysis, tests and experimental applications of the various conservative intervention techniques); functional recovery aimed at enhancing and improving the use of the heritage asset, with attention to sustainability and accessibility.
On completion of the second year, the trainee acquires the following knowledge and develops the relevant skills:

- A conscious and critical use of the findings resulting from the analytical and diagnostic phases of the first year and their integration where necessary.
- The identification of the general objectives to be pursued with the project and the strategies to achieve them through a gradual focus (from the planning report to the technical project report).
- The motivation of the design choices with reference to contemporary methodological, disciplinary and cultural debate and to significant examples of interventions carried out.
- The adaptation of the project to the legislation (anti-seismic system, fire prevention, architectural barriers, containment of energy consumption…), identifying solutions consistent with the conservation objectives, in compliance with the specific features of the protected heritage asset (insulation in the areas of less architectural value, insulation of roofing without altering the shape and material, replacement of glass panes with conservation and restoration of the frames and, where unfeasible, fitting of news windows in addition….).
- The choice of the type of systems (heating, cooling, lighting, air treatment, controlled mechanical ventilation, micro-generation) required and most suitable, in relation to the conditions of use, the needs for conservation and enhancement of the heritage asset and regulatory standards and current comfort.
- The choice of the most appropriate products to be used and the most effective intervention techniques to be used during the construction process, based on the specific needs of the heritage asset undergoing the intervention, the environmental conditions, their technical and commercial characteristics, in a cost-benefit budget (Figures 6, 7, 8, Tables 1, 2).

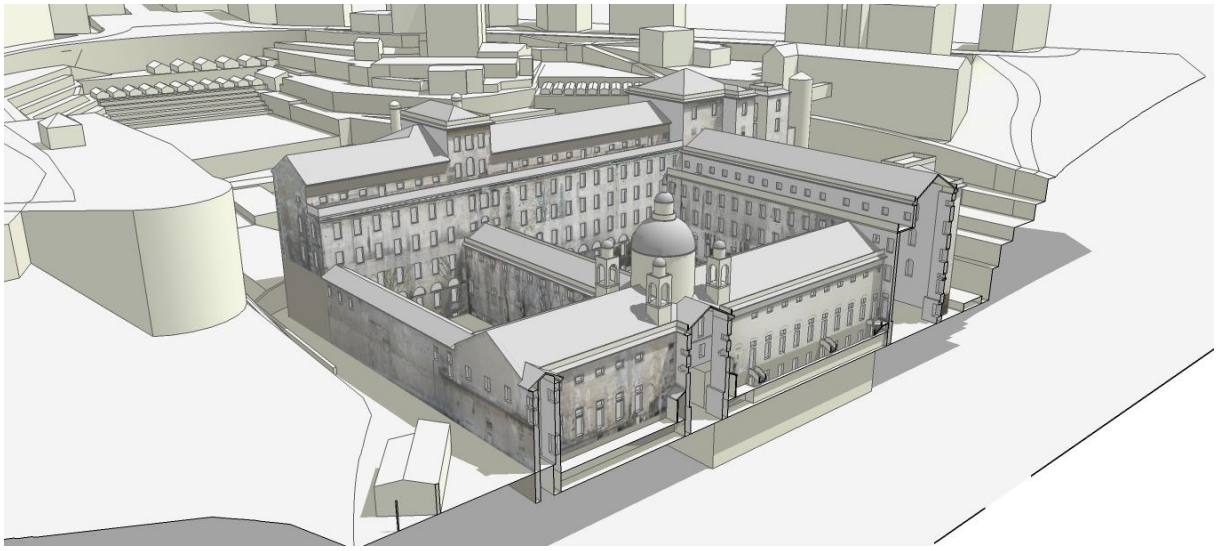

Figure 6 The *Albergo dei Poveri*, longitudinal section corresponding to the western wing and, in evidence on the left, the *Oratorio degli Uomini*.

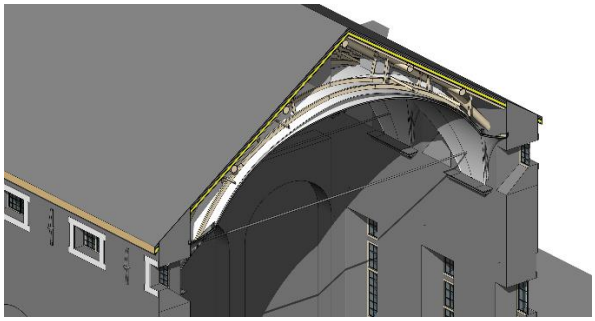

Figure 7 The *Oratorio degli Uomini*, one of the main wings to be renovated, BIM model (R. Babbetto). The design solution previews a new insulating layer under the roof.

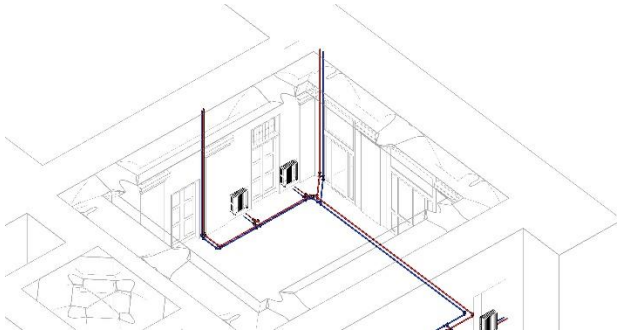

Figure 8 BIM model of one of the old spaces; the two lines indicated the old thermal plant pipes (XX C.), deriving from archive. The design previews the reuse of these old traces.

Table 1. *Albergo dei Poveri* in Genoa: total energy demand in the spaces to be renovated and re-used (around 60.000 square meters.

Electric (kWh)	Thermal (kWh)
956.000	2.496.000

Table 2. *Albergo dei Poveri* in Genoa. Feasibility study for a micro-generation system (installation of n. 2 micro-turbines for co-generation).

Thermal energy (unit 1+2) 1.456.908 kWh/year		Electric energy (unit 1+2) 872.400 kWh/year	
Winter	Unit 1 24 h/day 6 months	Unit 2 12 h/day 6 months	Day (thermal+electric)

Summer	Unit 2 12h/day 6 months	Night (hot water) Day (thermal+electric+hot water)

6. Conclusions

In addition to its educational effectiveness, the interest of this didactic initiative lies in the curiosity, the aptitude for scientific research and the desire for experimentation that distinguishes the main players (the 'client', protection bodies, the teachers and the future specialists involved). The traditional approach of an architectural restoration project aimed at the full conservation of the material is integrated, from the first design stage (concept), with various technical and plant system competences, each with its own background (measurement and control system calculation methods). From the experiments started a decade ago, an interesting work group was created, able to skilfully contribute with one's own strengths, even without resorting to multi-criteria analytical methods. All this giving to the architectural and tangible value as well as the significance of the built work that primary role that it must continue to maintain, albeit taking into consideration other systems. In this ideal 'consultation group' the representatives of the world of protection should be involved, being increasingly aware of the significance of the problem and the need to share commonly approved approaches and guidelines [13]. With these results, the School was able to increase awareness of the importance of energy efficiency among public institution owners of valuable heritage, private citizens and professional bodies by organizing detailed studies, public conferences, training seminars (lifelong learning for those enrolled in the professional register) as well as by drafting specific feasibility studies.

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