Conference Paper

Built Environment Education Across Boundaries. The Case of Energy Retrofit As a Tool for Low Carbon Transition

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Abstract

Since the 1990s, several studies have focused on the concept of Transformative Pedagogy as a strategy to foster inter-disciplinary abilities to rise to the challenge of sustainable development. Although the impact of these transformative pedagogies is widely recognised, their integration in traditional educational programmes is often neglected, specifically in programmes that develop future practitioners in the built environment (BE). In this realm, research has promoted the integration across disciplines as a key element to build locally appropriate technological solutions to deal with energy issues both at building and urban scales. However, the lack of inter-disciplinary training and tools necessary to support the understanding of complex problems within an inter-disciplinary context has remained an issue. This project deals with this lacuna by developing an innovative learning platform for knowledge integration in Energy Retrofit (ER). This paper starts with an overview of the methodological approach, which was used to configure the main structure of the cognitive tool (i.e., cmapER). Then, the results of the workshop which involved twelve senior researchers with different backgrounds (e.g. economists, architects, planners, engineers and project managers) in a mutual process of knowledge exchange, are presented. The main findings point out a set of new functionalities and properties of the CmapER as a cognitive tool that can stimulate interdisciplinary perspectives in ER. This contribution represents a further development on the combined use of cognitive mapping technique and meaningful learning activities in the realm of BE disciplines.

Keywords: Cognitive Approach, Cognitive Tool, Knowledge Integration, Interdisciplinarity, Trasformative Pedagogy.

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1. Introduction

Interest in the pedagogical aspects of sustainable development has grown during the last three decades. Higher Education has gained a critical role in the development of competences that are necessary to deliver a sustainable built environment [1], e.g. collaborative working [2], the ability to explore and solve complex problems [3]. Consequently, the learning process has recently become more complex [4] and traditional

theoretical and practical learning approaches became less appropriate to deal with the emergent demands of this complexity [5].

Several studies have investigated the new pedagogical principles for sustainability. Vassigh and Spiegelhalter [6] have emphasized the importance of self-directed learning, which can also be supported by Information and Communication Technologies for developing a new set of pedagogical strategies. Wang et al. [7] have focused on transdisciplinary exercises which are managed by teachers as facilitators of learning who guide learners in developing their understanding of the problems holistically and take actions at individual and collective levels. Other studies have promoted the need for a transformative pedagogy that engages learners in a deep inquiry-based learning process [8].

Although the impact of these pedagogical principles on sustainability education is widely recognised, the integration of such transformative pedagogies in educational programmes is often neglected. There is a need to eradicate practical and institutional obstacles that still stand in the way of such integration [9]. One of the main obstacles is the methodological training curricula and programs at graduate and post-graduate level based substantially focussed a mono-disciplinary perspective [10]. Even if, the sustainability is integrated at the conceptual level, such mono-disciplinary courses are not able to prepare the future practitioners to become holistic thinkers and problem solvers and universities continue to be a collection of disciplines rather than a place of ideas [11].

This study aims to address this issue by developing an innovative approach to introducing transformative pedagogies in Higher Education. This work is undertaken in the context of the built environment professionals. The process of developing an innovative cognitive learning tool for knowledge integration in Energy Retrofit (ER) is described. ER is considered beyond its traditional boundary of technical issues as tool for a Low Carbon Transition. It thus relates to both physical and social aspects of the disciplines of the built environment.

This contribution presents the rigorous methodological apparatus used to build the new cognitive tool, called CmapER, and argues that it is transferable to other areas. Perhaps more importantly, the results of the first evaluation of the content and functionalities of this tool by twelve senior researchers from different disciplines, are discussed. Findings show the excellent feedback received by participants who have pointed out that the tool inherits some cognitive properties that are useful to stimulate users' prior knowledge and support the transfer and integration of disciplinary perspectives.

2. Building and Implementing an Innovative Cognitive Tool: The Case of CmapER.

This section describes the procedure to build and implement a cognitive tool to support a built environment education approach across boundaries. This procedure was used to set up CmapER in two phases: i) Elaboration of content and structure; ii) their implementation and adaptation. Table 1 provides a brief description of the main features of the approaches adopted in order to provide the reader a greater understanding of the methods used, and to enable other researchers to repeat exercise to implement this approach in other contexts.

The first phase is articulated in the following steps:

1. Defining the main cognitive structure of the tool. The objective is to gather and organise information concerning the topic investigated (e.g. Transdisciplinarity in Energy Retrofit). Here, the cognitive structure was defined in terms of: *a*) categories; and, b) lines of research as main components of an innovative Conceptual Framework. Constructive Grounded Theory Method (CGTM) [12] was adopted as qualitative approach to conduct a literature review. 136 peer-reviewed journal papers were coded as part of this process. This approach was considered particularly useful in elaborating a cognitive learning tool, because it stimulates users' point of view in a continuous process of adaptation.

2. Validating the cognitive structure. The objective is to validate the Conceptual Framework through the saturation process of categories and lines of research. In CGTM, Saturation Process enables adequate levels of data to be gathered to populate the categories and establish the lines of research that were previously defined in the literature. Here, the saturation process included two levels of analysis: *a)* the evaluation of ER case studies; *b)* the contextualization of the cognitive structure. These two levels of analysis are autonomous and independent of each other. They were used both to validate the Conceptual Framework and to provide a more complete learning tool.

Two analytical approaches were followed. Firstly, a Diverse Case Method (DCM) [13] was used in order to integrate the selected case studies. DCM facilitates the consideration of the full range of variations on single concept (e.g. x and y) as well as, their relationships (e.g. x/y). 10 case studies were analysed. Each case study represented a specific geographical condition and building type (e.g., x=museum in France; x=social housing in Spain). They also related to a well-defined aspect of Transdisciplinarity in

Energy Retrofit (e.g., y= -building use; y= profiles of energy poverty). The contribution of each case study was elaborated using the Cognitive Mapping Technique [14], where each case study was associated with a specific Focus Questions (e.g., How to enhance the relation between architecture and citizens? What are the strategies to reduce energy poverty?). Results of this step have already been published [Anonomous].

The second step of the literature review was to analyse on empirical evidence from the UK in order to contextualize the cognitive structure in the geographical location where the tool will be tested. A further 77 peer-reviewed journal papers were evaluated as part of this process [16].

1. Building the Ontology (about the phenomenon of interest). The objective is to move from a traditional representation of the conceptual framework to its representation as a cognitive map. The term Ontology refers to a body of knowledge describing some domains of knowledge, using a representation vocabulary (i.e. concepts, properties of concepts, and relations between concepts). Here, the Ontology was founded on a process where: *a)* the hierarchical order among concepts is established; *b)* the relationships between concepts are distinctively expressed. The Ontology construction was also supported by the Cognitive Mapping Technique [14]. A cognitive map was produced in a computer environment i.e., IHCM-tools platform, which is a free software and facilitates the storage of the cognitive maps on a server as Open Education Resources.

The second phase regards the implementation and adaptation of the cognitive tool. It main consists of: three workshops for experts, postgraduate and undergradatue respectively. This paper focus on the workshop for experts which involved n.3 architects, n.3 planners, n.3 economists, n.3 engineers.

Here, the aim was to assess cmapER in terms of its capacity to stimulate knowledge integration and transfer between different fields of expertise and thus to go beyond disciplinary boundaries. The first testing of the tool also took place. The participants were actively engaged in the use of CmapER through the application of a combined use of Cognitive Mapping Technique [14] and Meaningful Learning Activities [17].

At the end of the workshop, feedback from participants was collected using an anonymous questionnaire, audio recording of the discussion sessions and maps that were articulated by the participants both individually and collaboratively. A second step, which is currently in progress, will involve both undergraduate and postgraduate students in a sequence of testing activities.

TABLE 1: Methodological Framework: the development and implementation of CmapER.

Methods and References	Description of the main features
Constructive Grounded Theory Method (CGTM) [12]	CGTM derives from the Grounded Theory which is a well known qualitative approach for exploring phenomena. A a major advantage of CGTM is that it considers knowledge processes as processes of social exchange and the exploration of the phenomena is always contextualized in its social, cultural, and physical context. Inherent bias in the approach and its limitations are considered. Therefore, in CGTM, the resulting theory "*depends on the researcher's view; it does not and cannot stand outside of it*" ([12], p.239).
Diverse Case Method (DCM) [13]	The Diverse Case Method has two appealing features. First of all, it is a unique approach that can be used both for exploratory and confirmatory purposes. Seawright and Gerring explain how diverse case method works: ["*It requires the selection of a set of cases, at minimum, two, which are intended to represent the full range of values characterizing X, Y, or some particular X/Y relationship. The investigation is understood to be exploratory (hypothesis seeking) when the researcher focuses on X or Y and confirmatory (hypothesis testing) when he or she focuses on a particular X/Y relationship*"] ([13], p.300).
Cognitive Mapping Technique (CMT) [14]	CMT is an approach for organizing and representing knowledge. The maps include concepts and relationships between concepts. There are two features of concept maps that are important in the facilitation of creative thinking: the hierarchical structure that is represented in a good map and the ability to search for and characterize cross-links. The first step is to identify the key concepts with regard to a specific Focus Question. These key concepts represent the user's prior knowledge. The next step is to construct a preliminary concept map (or integrate these concepts in a map e.g., CmapER), and thus identify new focus questions. Once a preliminary map is constructed (or concepts are introduced in it), cross-links should be sought. These are links between different domains of knowledge on the map that help to illustrate how these domains are related to one another.
Meaningful Learning Activities (MLAs) [17]	The Meaningful Learning Activities are so divided: i) Observant and manipulative: "Users" can manipulate objects and parameters and observe the results of their manipulation. ii) Constructive and reflective: The meaningful learning demands "Users" to articulate their activities and observations and reflect on how to integrate prior knowledge with new information. iii) Intentional and goal-directed: Users must be able to set their own learning goals and monitor their advances. iv) Complex and contextual: Learning is more readily transferable to new situations when it is associated with real-life problems. v) Collaborative and conversational: Users should do much more than simply access or seek information; rather they should know how to examine, perceive, interpret and experience information.

3. Results from the First Testing Activity. The Interdisciplinary Workshop for Researchers.

The key outcome of phases 1 and 2 was a ground-breaking conceptual framework on Transdisciplinarity in Energy Retrofit. It was articulated in 5 categories and 3 lines of research in each category (i.e., From Building Retrofit to Urban Retrofit; Technical and Social-Integration; Disruptive and Sustainable Local Technologies; Energy Modelling

Process; Occupant Behaviour Modelling; Life Cycle Assessment; Multi-Attribute Information; Bottom-up Methodologies; Economic and Socio-Technical Factors; Innovative Building Materials; Passive, Active and Smart Technologies; Shifting the Industry; Integrated Community Energy System, Comfort and Quality of Life; Socio-Technological Learning Process), giving a total of 15 lines of research. In Phase 3 the Conceptual Framework was represented as a cognitive map (Figure 1). Categories and Lines of Research became the Domains of Knowledge. They were organised with regard to the main focus question (i.e., what are the main questions concerning the concept of Energy Retrofit as a tool for Low Carbon Transition?) and hierarchically distributed within the map. All concepts were connected by specific linking phrases to form a sequence of propositions, promoting a meaningful discourse. CmapER visualises a piece of interdisciplinary knowledge on Energy Retrofit as a tool for Low Carbon Transition, providing a common platform which is ready to be adapted or adopted according to the users' prior knowledge.
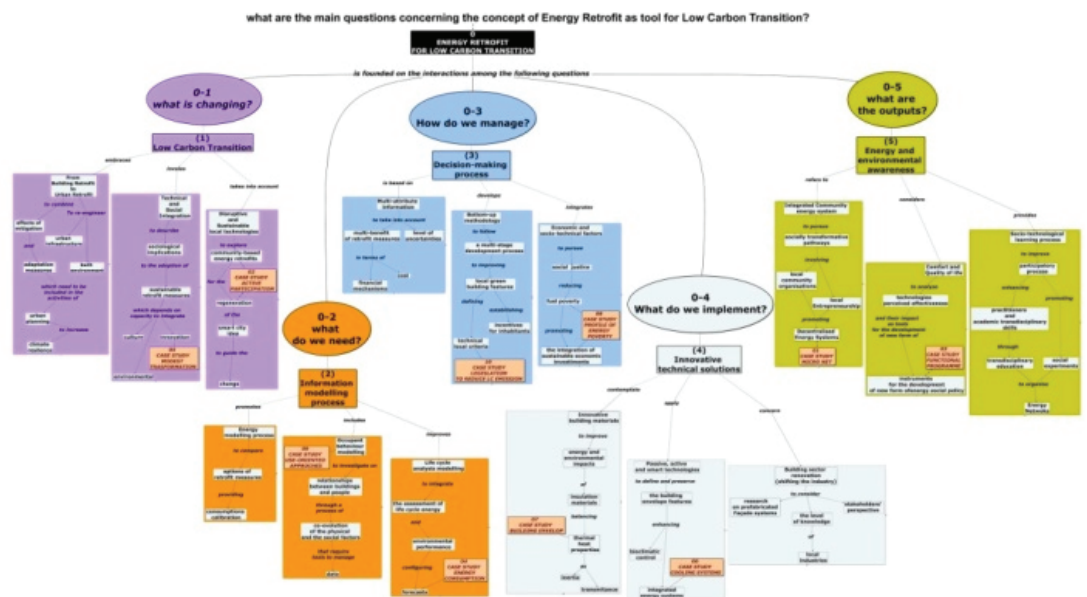

Figure 1: CmapER Domain of Knowledge.

The users' prior knowledge is presented in the Table 2, which shows in detail the background and the fields of the expertise for each participant. By using CMT and MLAs in conjunction, participants: a) developed an individual list of key concepts; b) integrated these concepts into the framework of CmapER; c) discussed their integration with a partner; d) combined interdisciplinary perspectives; e) debated the results of this combination among all participants.

Figure 2 illustrates an example of CmapER adaptation. What is interesting in this data is that each participant focused on a specific domain of knowledge suggested by

the map, promoting original connections among the existing concepts and providing new concepts and relationships to describe personal points of view. For instance, the domain of knowledge of Innovative Technical Solutions was involved in three completely different perspectives: a) the user (P10) advocated some clarification on the concepts of this domain, working at the detailed level; b) the user (P06) tracked new connections between some concepts of this domain and the other two domains (i.e., Low Carbon Transition and Occupant Behaviours Modelling), building up a completely new hierarchical organisation of the concepts; c) user (P07) sought to re-establish the principal relationships among the domains, working on new connections rather than new concepts.

TABLE 2: Fields of expertise of the participants of the workshop.

Participants	Key concepts as prior knowledge (selection)
P01-Business and Management	Corporate Governance; Behaviour Change; Energy Conservation
P02-Urban Studies and Economics	Governance; Green Economy; Participation
P03-Business and Management	Pro-environmental Behaviour; Green Policy; Energy Efficiency
P04- Finance and Economics	Circular Economy; Climate Change Adaptation; Renewable Energy
P05-Environmental Engineering	Technology Adoption; Socio-Technical Transition; Innovation
P06-Environmental Engineering	Building Physics; Energy Modelling; Decision Making
P07-Architect	Project Management; Risk Analysis; Environmental Risk
P08-Environmental Engineering	Low Carbon Technologies; Building Performance; Indoor Environment
P09-Architect:	Energy Consumption; Energy Performance; Occupant Behaviour
P10-Civil Engineering	Energy Assessment; Decision Making; Renewable Energy
P11-Urban Design and Planning	Equitable Access to resources; Global Responsibilities; CO2 Emissions
P12-Urban Design and Planning	Decision-making process; poverty reduction; local economy

Table 3 exposes some relevant passages that were captured during the discussion phase, while Table 4 reports on the feedback received form the anonymous questionnaire.
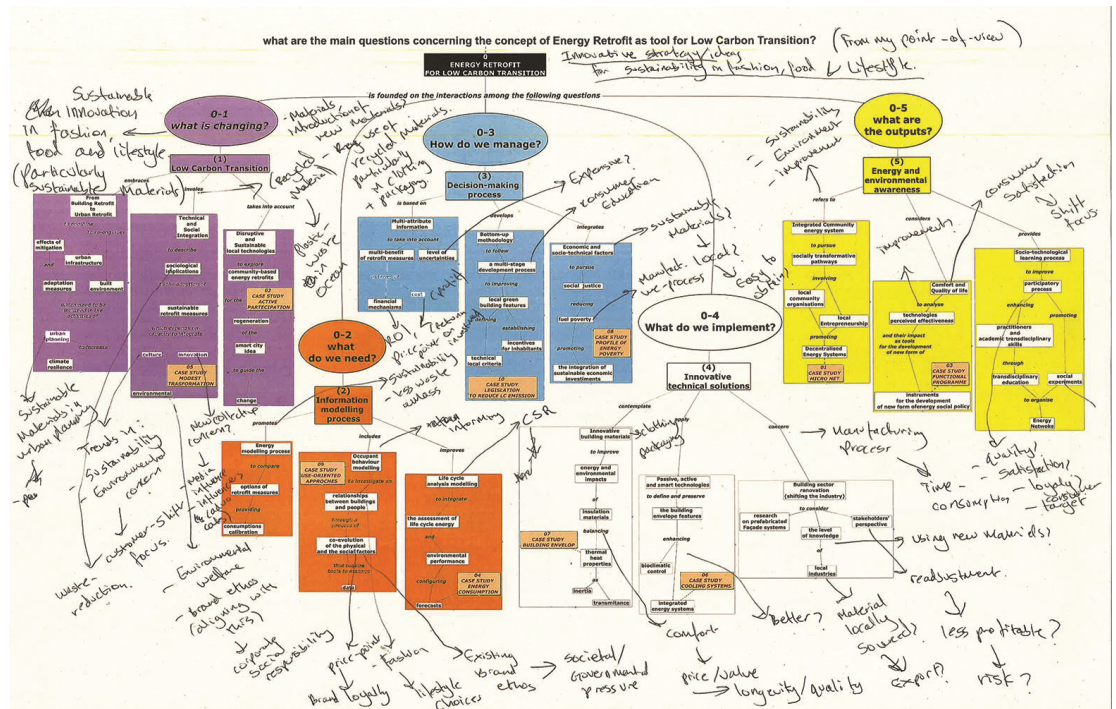
Figure 2: Example of manualCmapER adaptation.

4. A Cognitive Tool to Work Across the Disciplinary Boundaries: Lessons Learnt

Prior studies have noted the importance of Transformative Pedagogy to deal with the sustainability in Higher Education [1-8]. This study set out to assess a specifically-designed cognitive tool in order to facilitate knowledge integration and transfer among built environment disciplines. The current study found that the approach adopted might be useful for understanding the opportunities to work collaboratively by stimulating a meaningful dialogue among participants with different perspectives and scopes. In this study, three relevant results emerged. CmapER is useful: a) to better comprehend how concepts are used in different disciplines and develop a common vocabulary; b) to establish a boundary for an interdisciplinary discussion, which are often too dispersive or generic; c) to stimulate the identification of new focus questions and the introduction of new concepts and relationships in a complex framework.

These results are in line with both the theory of cognitive approach [14] and meaningful learning 17], promoting an innovative apparatus to integrate physical and social sciences in the built environment. Although the number of participants was limited, all of them have a relevant experience in higher education and, at the end of this experience, all of them have confirmed that CmapER may be considered a useful tool to integrate interdisciplinary topics into the traditional courses and modules.

TABLE 3: Recording unit report.

Groups	Coding from recording units:
G01 P04 & P07	[...] *we see "low carbon technologies" together with "users' interactions" and we have linked these relations with other groups* [proposed by cmapER]. [CmpER] *was useful to clarify the use of terminologies* [...] *and also to establish why one concept needed to be placed in a domain over another* [...].
G02 P05 & P08	[...] *it was useful to start sharing a common point of view* [Climate change and social aspect of transition]. *We have also used the suggested concepts to introduce a new topic* [social migration] *and questions* [how to engage people to drive innovation?]. [...,cmapER] *was useful in particular to establish a boundary of our discussion. It was useful to orientate and stimulate the discussion.* [...]
G03 P06 & P10	[...] *it was useful to visualise the use of concepts even if the map is not exhaustive.* [...] *we have included more information about some concepts.* [...] *When we read the category we were stimulated to create new focus questions* [e.g.,Who are the actors (in energy transition)?]. [...] we *need time to gain confidence to use the map in terms of content and functionalities* [...].
G04 P03 & P11	[...] *we shared a common vocabulary* [...] *we focused on concepts as "social justice", "global responsibilities" connected with "innovative technical solutions"* [...]. [...] *we pointed out the important factors concerning the environment awareness* [...] *and the need to better understand the condition of success to improve pro environmental behaviour* [...]
G05 P01 & P02	[...] *we have included new concepts in the map to represent our interests "Green economy", "privatization of urban Infrastructures", "Corporate governance"* [...].[...,cmapER] *has stimulated a discussion on the role of different levels of governance and their interactions as relevant components of energy transition.*
G06 P09 & P12	[...,poverty reduction in urban environments] *we have placed this concept at the centre and we have connected this with decision making* [category] *underlining the importance to build a network to deal with this concern* [...]. [...] *we have tried to put together the concept of "energy poverty" with that of "environmental performance" establishing some common strategies* [...]. [...] *we have included more detail on the concept of "environmental performance"* [included in cmapER] *because it is quite generic* [...]

This experience has also revealed some limitations. Although the CmapER was able to visualize a piece of knowledge, its structure inherited some deficiencies. For example, at the beginning of the workshop participants tried to understand the map as a tool with complete information and not as a tool to stimulate a cognitive process, because of the well-defined structure of CmapER. Participants suggested to include some empty boxes in order to communicate the dinamic state of the map. This was a good suggestion, even if it emerged mainly due to lack of participants' knowledge of the cognitive mapping technique. Futhermore, the participants stated that they need more time to gain confidence in the tool, given that it includes a lot of concepts. Therefore, in the next test we will extend the map reading period from 20 minutes to 40 minutes.

TABLE 4: Feedback from the anonymous questionnaire.

Question (1) strongly disagree; (2) disagree (3) agree;(4) strongly agree	(1)	(2)	(3)	(4)
1.This is the first time I used this approach	-	1	3	8
2.I consider that the exercise of producing a list of concepts helped me to understand how to use my prior knowledge	-	-	6	6
3.I consider that the exercise to integrate my knowledge with CMAPER was helped me to find out connections among concepts	-	1	5	6
4. I consider that the exercise to integrate my knowledge with CMAPER was helped me to identify relevant issues in brief time.	-	1	7	4
5. I consider that the comparison and discussion of the resulting Cmaps with others helped me to exchange information	-	-	6	6
6. I consider this approach to be useful for understanding the opportunities to work collaboratively	-	-	5	7
7. I consider that this approach was helped me to understand how to integrate my knowledge into a more complex, existing framework	-	-	5	7
8.I consider this approach was useful for better understanding the relevant concepts and their relationships	-	1	3	8
9. I consider this approach was useful for stimulating a meaningful dialogue with other participants	-	-	3	9
10. I consider CmapER as useful tool to integrate interdisciplinary topics into the traditional courses/modules	-	-	3	9

5. Conclusions and Future Perspective

In conclusion this study confirms that the combined use of CMT and MLAs may be considered as a valid approach to introduce Trasformative Pedagogies in the built environment in order to facilitate interdisciplinary education. The first testing activity has assessed how the cognitive tool may support an effective dialog among the disciplines. This approach seems to be appropriate to deal with the built environment issues which involve a plurarity of perscpetives and scopes. The next phase of this study will involve a group of Undergradute and Postgraduate students to assess and implement the funcitonlites of the CmapER.

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Conflict of Interest

The authors have no conflict of interest to declare.

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