# A MODEL FOR INTEGRATING ENVIRONMENTAL SUSTAINABILITY INTO ARCHITECTURAL EDUCATION

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## ABSTRACT

*This article proposes a model for integrating environmental sustainability into architectural education that derives from the analysis of sustainable architectural design in practice. The research methodology is based on nine case studies of architectural practices that are pioneers in environmentally sustainable design. The design process of a building from each practice was mapped using information gathered by interviews with the members of the design team, plans, diagrams and sketches. The case studies highlight the skills and knowledge that the architect needs to acquire to integrate sustainability into the design process. This reveals that architectural education might focus on developing attitudes, explicit knowledge, tacit knowledge and skills that interweave intuitive, analytical and social dimensions in a holistic manner.*

## KEYWORDS

architectural design; design education; environmental design; intuitive design; design tools

This article proposes a model for integrating environmental sustainability into architectural education that derives from the analysis of sustainable architectural design in practice. Although academia has traditionally led practice in the field of sustainable design through education and research, since the mid 1990s a growing number of buildings designed by experienced and committed architects have created a valuable field of inquiry. Therefore, this article is based on a bottom-up approach that aims at learning from practice.

The methodology is based on the qualitative research tradition of case studies, which refers to the exploration of a number of cases over time through detailed in-depth data collection, involving multiple sources of information, rich in context (Yin, 2003). This research method has proved to be valuable in retaining the holistic and meaningful characteristics of the design process as a real-life event, making it possible to transfer this information into a holistic model for education.

The case studies are drawn from the work of contemporary architectural practices considered pioneers and leaders in environmentally sustainable architectural design. The first part of the research work examined case studies in Europe as part of a PhD thesis, while follow-up research was carried out in Chile as part of a nationally funded project. The criterion for choosing the case studies was based on sampling of selected information-rich cases for in-depth study.

Each case study contains an embedded unit of analysis consisting of the design process of a non-domestic environmentally sustainable building designed by each practice. The architects selected the buildings they considered most interesting in terms of integrating sustainability issues into the design process, rather than those constituting the most sustainable or energy efficient solutions in their specific contexts. The selection process responded to a socio-constructivist approach that avoided having to impose a particular definition of sustainable buildings, but included a variety of possible definitions suggested by each architect.

The sustainable buildings and the architectural practices that comprise the cases studies of this study are: Heelis by Feilden Clegg Bradley Architects (UK); The Business School at the University of Nottingham by Hopkins Architects (UK); Downland Gridshell by Edward Cullinan Architects (UK); Hines building by Mario Cucinella Architects (Italy); the NORD/LB by Behnisch Architekten (Germany); SONDA building by Enrique Browne (Chile); FASA building by Guillermo Hevia (Chile); Multimedia UACH by Roberto Martinez (Chile); and ACHS Headquarters by Saerle, Puga, Swinburn (Chile) (fig.1).

The design process of each building was mapped using multiple sources of information, including semi-structured interviews with architects, engineers and clients; the compilation of various types of documents that recorded the design process (architectural drawings, sketches, reports, multimedia presentations, etc.) and observations of the buildings themselves.

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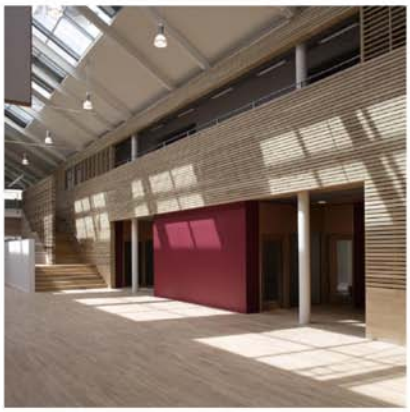
**FIGURE 1.** Case studies.



*Heelis, UK, Feilden Clegg Bradley Architects*

*Business School, UNott, UK, Hopkins Architects*

*Downland Gridshell, UK, Edward Cullinan Arch.*

*Hines building, Italy, Mario Cucinella Architects*

*NORD/LB, Germany, Behnisch Architekten*

*SONDA building, Santiago, Enrique Browne*

*FASA building, Chile, Guillermo Hevia*

*Multimedia building, Chile, Roberto Martinez*

*ACHS HQ, Chile, Searle, Puga, Swinburn*

## 1. LEARNING FROM PRACTICE

### *1.1 The Intuitive/Analytical/Social Model of the Design Process*

The analysis of the case studies suggests that the integration of sustainability issues in architectural design occurs as two complementary processes of intuition and analysis within a framework of social interaction. The intuitive process is based on knowledge and experience of the members of the design team and guides early and fundamental design decisions. The analytical process is dominant at late stages of the process and is guided by the use of design assisting tools to inform and check design decisions.

It is important to note that the design process in practice is much less systematic and messier since the situation is more fluid and less bounded than the diagram shows (fig. 2). The diagrammatic representation is a heuristic device rather than an accurate representation of the nature of the process in all situations, but it certainly helps to identify the main dimensions of the process.

The case studies suggest that the generation of the initial idea is the result of a social process of interaction of different types of expertise. Architects and engineers (or energy consultants) start working in close collaboration from the beginning of the design process to the point where on occasion both parties share the authorship of the initial idea. In addition, analysis plays a crucial role in the design process, going beyond the common notion of analysis as the process of qualitative appreciation and re-appreciation of the design situation (Schön, 1991), into a process of quantitative assessment that informs design decisions, supported by analytical tools.

Quantitative analysis is intrinsically linked to the technical challenges of sustainable architecture and was present in all case studies, but at different levels of sophistication depending on the complexity, innovation and risk involved in the project. The role of the analytical process is particularly important during the middle to late stages of a project, and the whole process may be understood as a reflective interaction between intuition and analysis. Before embarking on extensive analysis, the design team would use intuitive elements to generate ideas, while subsequent analysis would allow them to form a better understanding of the environmental problems to reiterate in reflective practice.

### *1.2 Knowledge and experience*

The intuitive dimension of the design process does not mean that design decisions are taken arbitrarily or capriciously; rather they are taken without the intervention of any structured reasoning process. Although many people assume that intuition is instinctive or innate, it rather depends on prior experience that generates learned responses. Comments by the interviewees confirmed this when they claimed that *"most of the design decisions have been made based on experience"* (Thomas Auer, energy consultant of NORD/LB from Transsolar, interview); and that *"a normal process of design would be to put ideas on the table; to work together with the architects and engineers to look at the impact of those ideas on the design. And that would be done probably mostly by experience"* (Alistair Guthrie, energy consultant of Hines from Arup, interview).

Many authors agree on the important role that knowledge and experience play in architectural design. Architects generally face the design project with a store of knowledge about what has led up to it (Beach, 1990) and with a certain level of maturity that allows them to practice sound design (Lawson, 2004). Both knowledge and experience in architectural design are closely interrelated. Unlike other disciplines, design knowledge is deeply dependent on experience because designers acquire and use predominantly experiential knowledge in a process famously described as *"designerly ways of knowing"* (Cross, 1982).

Design knowledge can be conceptualised as tacit knowledge as opposed to explicit knowledge (Polanyi, 1967). Tacit knowledge is acquired over time and rooted in experience, so it is deeply embedded in the knower. On the contrary, explicit knowledge relates to academic and theoretical knowledge, rooted in research (Heylighen, A. Neuckermans, H. and Bouwen, JE., 1999).

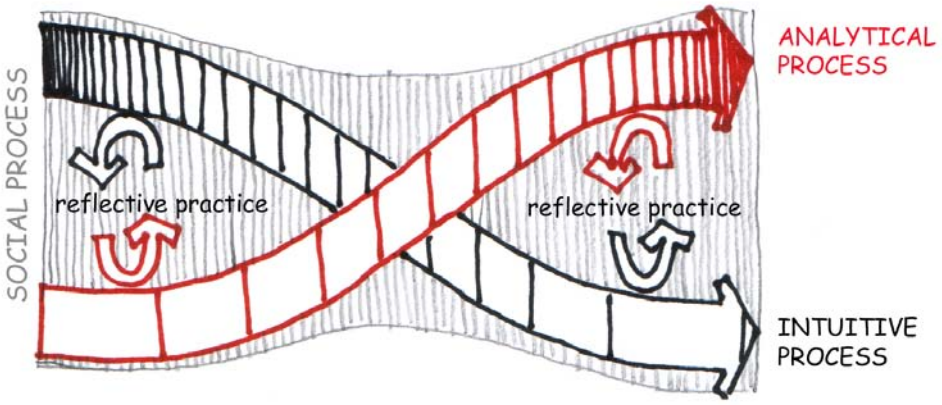



**FIGURE 2.** The Intuitive/Analytical/Social model of the design process.

The case studies suggest that the innovative and experimental nature of sustainable architectural design places great importance on both tacit and explicit knowledge. Not only is the knowledge that the designer acquires through experience important when making a design decision, but so is the knowledge obtained from the academic and research environment. The interviewees prove this fact when they claim that they gain knowledge in sustainable design by reading and attending seminars and CPD courses on new technologies and methods, while they share and develop their knowledge in practice, as Edward Cullinan states: *"Our system of sharing knowledge and information is for all 30 of us to work in one room"* (Edward Cullinan, interview).

The relevant explicit knowledge in sustainable design identified by the architects was very broad, covering a variety of aspects from comfort and energy efficiency to cost analysis. Both European and Chilean architects believe that explicit knowledge is broad and dispersed, and its sources of information could sometimes be questionable. Some interviewees identified this problem as a major barrier to sustainable design and pointed out the need for consensus regarding valid knowledge that could help to guide practitioners in the right direction.

Remarkably, every architect and engineer interviewed in this study claimed that their early conceptual schemes were based on knowledge and experience, rather than on any specific design-assisting tool. The tools came later in the design process.

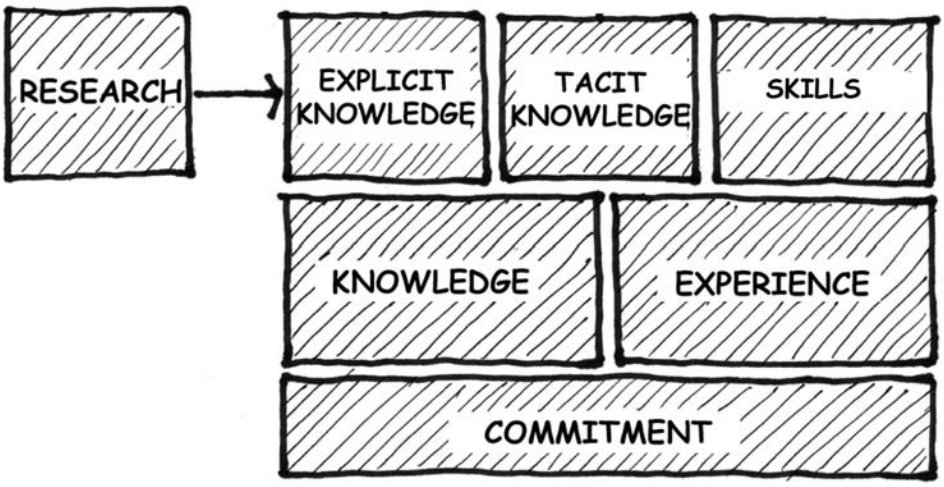
In addition, most interviewees believe that commitment to sustainability allows the designer to develop the relevant knowledge and experience that they need to tackle the challenges of sustainable design. Edward Cullinan believes that *"if the commitment and interest is there, then the knowledge will grow"* (Edward Cullinan, interview). Therefore, commitment is the essential driving force for the work of both the experienced and the novice designer.

Based on these facts, fig. 3 proposes the foundation stones of the design process, where commitment is the base stone; knowledge and experience are on the second level and supports the third row of stones consisting of explicit knowledge (based on research); tacit knowledge (based on experience and research) and skills (based on experience).

The case studies help to explain the role that experience plays in the inclusion of sustainability issues in the design process. Although all the architectural practices were chosen as case studies due to their expertise in sustainable design, which could introduce a degree of bias in that respect; it is interesting to note that every architectural practice chose an engineering practice of experts in sustainable design to join the design team. Buro Happold, Transsolar, Arup and Max Fordham have an international reputation for their vast knowledge and expertise in the field, illustrated not only by their building projects but also by their research and publications. At a more local level, the consultants Rolf Thiele, Joaquín Reyes and Jorge Ramírez are well-known for their expertise in energy efficiency and sustainable design in Chile and Latin America.

Setting up an experienced design team was the first fundamental decision that every architect made to take on the challenge of designing an environmentally sustainable building, by enhancing the collective knowledge and experience. In most cases the architects were the driving force of sustainability; their expertise and commitment had the fundamental role of introducing and pushing the sustainability agenda

**FIGURE 3.** Base stones of the design process.



from the moment they were appointed. Only when the architects were less experienced in sustainable design was it the engineer who pushed the sustainability agenda with the support and commitment of the client.

During the design process, the architects' approach to instances of uncertainty, ignorance and innovation was to find an expert to assist them in dealing with each specific problem. The approach was expert-based rather than tool-based; instead of looking for another tool or guideline, the architect looked for an expert, who in turn used his/her own experience in dealing with the design problem and complemented the experience with an appropriate analytical tool.

The case studies also suggest that the practice of sustainable design may be undergoing a period of transition where the increased knowledge and experience of the practitioners results in less and less reliance on analytical tools. An engineer interviewee gives an interesting example of this phenomenon: he states that when they have worked with architectural practices that are open to environmental sustainability issues but are less knowledgeable in the field they have been obliged to carry out simulations just to show the architects that certain strategies work. In contrast, when they work with experts, they do not need to perform much analysis, but start at a different level based on knowledge and experience.

The intuitive and the analytical processes are interrelated in such a way that the stronger the intuitive ability of the designer, the less their reliance on the analytical process; in contrast, the weaker the intuitive ability, the stronger is the role of the analytical process.

### *1.3 The role of the precedent*

The architectural precedent is recognised as an important source of knowledge in the design process because it embodies tacit knowledge developed from previous design experience. It is important to distinguish here between two kinds of architectural precedents: 'internal precedents' that refer to the designer's own past architectural projects and 'external precedents' that refer to projects developed by other design teams.

Architects have long relied on both kinds of precedents, either because the works of the past naturally influence their new work, or because they gradually develop their own unique style in architecture. Internal precedents embody mainly tacit knowledge that the designers have acquired from previous projects, while external precedents embody mainly explicit knowledge acquired through visits to the buildings or review of published information.

The case studies revealed that the design teams mainly referred to recent precedents, usually designed since the 1990s. This is probably due to the innovative nature of environmentally sustainable buildings that need to refer to the latest developments and cutting edge technologies, while also maintaining a contemporary appearance. Exceptionally, the nineteenth century industrial buildings of Swindon were used as a precedent for Heelis, thus placing more pressure on the contextual-historical side of the design. However, these historical buildings also provided interesting environmental insights for the new building, proving that basic environmental principles have informed building design over many centuries.

The strategy of relying on precedents to inform design decisions can be either intuitive or conscious, but it is certainly present in most architectural practices, as stated by several authors. Schön (1991, p138) claims that architects build a "*repertoire"* of examples and images that include sites and buildings they have seen and design problems and solutions they have encountered. Oxman (1994, p141) states that architects browse freely between multiple precedents in order to make connections with their new task in a process termed *"precedent-based design"*.

Hancock (1986) proposes that the precedents can be grounded in three realms of choice: place, type and principle. Designers connect place-grounded precedents to their new projects when they aim at contributing to the continuity and coherence of the location; precedents by type refer to culturally rooted form-function analogues; and precedents by principle connect new work to previous work by applying techniques that have proved to be effective under a variety of conditions. In this case there is no intention of creating a geographical and cultural continuity, but the most important continuity is that of effective techniques.

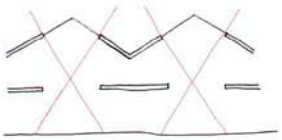
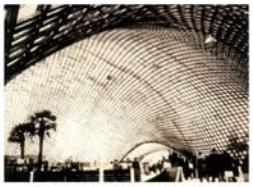
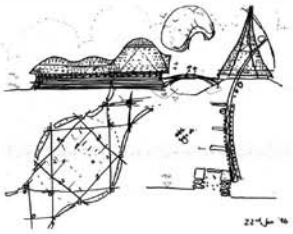
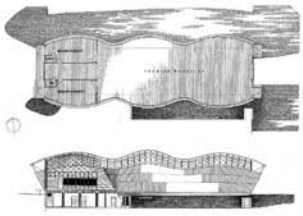
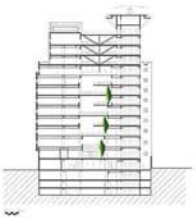
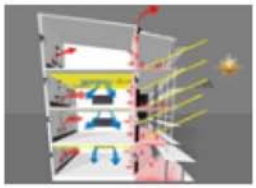
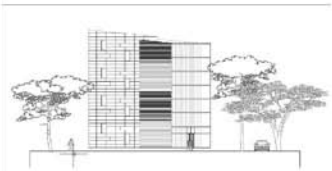
Table 1 summarises the precedents embraced by some of the case studies and categorises them against their internal or external nature and by the realms of choice.

It is interesting to note that the project and its precedents are all related by a principle of sustainable design: e.g. the roof as a climatic control element in the case of Heelis; the timber gridshell as an efficient structure in the case of Downland Gridshell; the courtyard as an internal oasis in the case of the NORD/LB; the use of greenery in the case of SONDA; and the solar space in the case of UACH.

Internal precedents were more dominant than external precedents, suggesting that expert designers rely more on their own experience than on the experience of others in the field. The use of internal precedents, i.e. the architects´ previous projects, helps to build a 'continuous design process' where each project is seen as the continuation of a previous project, based on the experience acquired. In some cases, the project is the first in a series of buildings where the architects introduced energy efficient strategies. For example, the expressive underground heat exchangers of the FASA building were replicated in various buildings designed by the practice in the following years.

It is important, however, to question the heavy reliance on knowledge and experience demonstrated by some of the case studies. It is also questionable to rely so heavily on precedents as a form of knowledge, as there is usually a high level of uncertainty regarding some buildings' final performance due to the lack of post-occupancy evaluation.

**TABLE 1.** Graphic relationship between precedents, first sketches and final drawings.

| precedents | | first sketches | final drawings |
|---|---|---|---|
|  *19th Century buildings external precendent by place and principle* |  *Lords Cricket school internal precedent (eng) by principle* |  *Heelis, UK* |  *Heelis, UK* |
|  *Hooke park internal precendent (arch) by principle* |  *Mannheim gridshell internal precendent (eng) by principle* |  *Downland Gridshell, UK* |  *Downland Gridshell, UK* |
|  *Bank in Stuttgart internal precendent (arch) by type and principle* |  *Research Centre internal precendent (arch) by principle and type* |  *NORD/LB, Germany* |  *NORD/LB, Germany* |
|  *Consorcio building internal precendent (arch) by type and principle* | |  *SONDA, Chile* |  *SONDA, Chile* |
|  *School of Architecture internal precendent (arch) by type and principle* | |  *Multimedia building, Chile* |  *Multimedia building, Chile* |

### *1.4 Closing the loop between intuition and analysis*

Based on the case study evidence suggesting that fundamental design decisions are guided by knowledge and experience, instead of promoting the use of analytical tools at early stages in the process, research and practice should concentrate on shifting the stage of analysis to fill the existing gaps between consecutive architectural projects in order to help build up concrete knowledge. This analysis takes the form of post-occupancy evaluation (POE); a valuable method of learning from experience.

Figure 4 proposes a diagrammatic representation of the continuous design process that is reached by closing the loop between the design processes of sequential projects by a stage of POE. This linking process feeds the knowledge of the designers and allows them to start the next project at a different—improved—level of knowledge and expertise that creates a solid base for the intuitive process. In addition, the analytical process is also reinforced by the inclusion of this linking stage because it allows designers to check and calibrate their design-assisting tools against real measurements.

The proposal of the continuous design process is based on the fact that in the same way that the stages of the design process are not well defined (detail design stage merges into construction stage, etc.), the boundaries between subsequent building projects are blurred within professional practice. This idea was underlying in all the case studies, where architects see their current projects as continuations of previous architectural projects and as precedents of future projects.

Most of the buildings that form part of this study have not been evaluated at post-occupancy stage, and only a few environmentally sustainable buildings previously designed by the architects have been evaluated. However, the evidence suggests that there is a process of 'informal feedback' from most buildings, based mainly on comments from the users. There is an informal thread that feeds back to the architects and engineers and helps build their tacit knowledge.

The importance of closing the loop of the design process by having POE is partly based on the fact that predicted performance can be over three times better than real performance (Roaf, S. Horsley, A. and Gopta, R. 2004).

Most of the case studies available in books and sustainable design guidelines lack information on this fundamental final stage of the process. The risk created by this omission lies in the possibility that designers replicate strategies and systems that have failed in previous projects. Considering the key role that precedents play in guiding design decisions throughout the design process and fundamentally at early stages, it is essential that sustainable design guidelines provide complete and truthful information on the case studies. Unfortunately, this is not always the case and architects sometimes receive shallow and partial information that could easily misguide them.

There is a point of interaction at the POE stage between the intuitive and analytical processes, as qualitative information can help to provide benchmarks for the analytical process, while quantitative information can help to build knowledge for the intuitive process. This point of interaction is very dynamic as quantitative and qualitative information can be used for a wide variety of purposes, closing the loop between different design processes, as well as between intuitive and analytical dimensions.

## 2. A MODEL FOR EDUCATION

The analysis of environmentally sustainable design in practice has important implications for architectural education as it highlights the necessary attitudes, knowledge and skills that the architect needs to acquire to integrate sustainability into the design process, while also pointing out the appropriate tools. The Intuitive/Analytical/Social model of the design process reveals that architectural education might focus on developing attitudes, knowledge and skills that interweave intuitive, analytical and social dimensions.

Considering that education in the context of sustainable design is a complex issue, this article only intends to highlight essential aspects of the architectural practices and designs studied, and identify certain emerging trends. Table 2 organises attitudes, explicit knowledge, tacit knowledge and skills around the three dimensions of the design process, highlighting only those that are essential for integrating environmental sustainability issues into architectural practice. Evidently,

**FIGURE 4.** POE and the continuous design process.

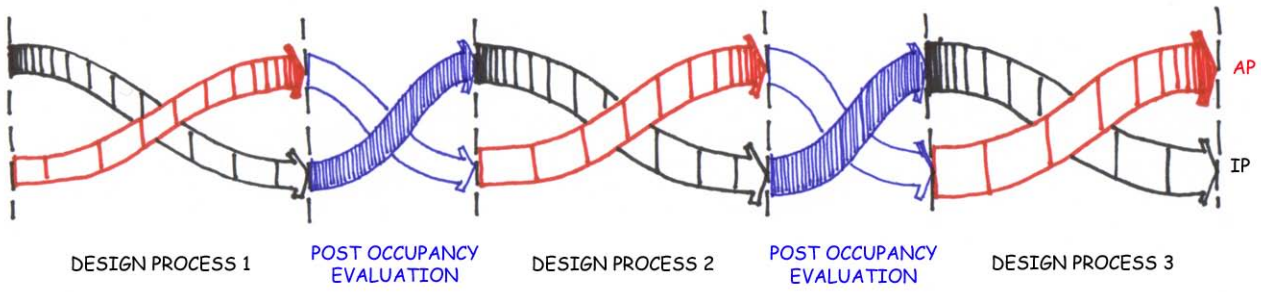


**TABLE 2.** A model for education.

| | ATTITUDES | EXPLICIT KNOWLEDGE | TACIT KNOWLEDGE | SKILLS |
|---|---|---|---|---|
| INTUITIVE PROCESS | Environmental ethics | Principles and strategies of environmentally sustainable design<br>Rules of thumb | Critical appraisal of case studies | Design integration |
| ANALYTICAL PROCESS | Analytical attitude | Architectural sciences | Quantitative analysis of case studies and the students' design projects | Use of analytical tools |
| SOCIAL PROCESS | Social engagement | Scientific and technical language | Analysis of socio-cultural context | Interdisciplinary teamwork<br>Effective communication |

there is no real delimitation between the three dimensions of the process, and attitudes, knowledge and skills are strongly related, bridging the different dimensions. In this way, knowledge of the principles of environmentally sustainable design is essential for the development of analytical skills; just as environmental ethics is necessary for engaging the client and the design team with the sustainable agenda.

### *2.1 Attitudes*

As mentioned earlier, the case studies bring to light the idea that the foundation stone of the intuitive process is commitment to sustainability, which architects consider to be the essential driving force for the practice of sustainable design and the development of the necessary knowledge and experience. This finding is meaningful, as education should be careful to avoid concentrating solely on the acquisition of specific knowledge and skills, leaving ethical issues aside. The first implication for education should be to embrace an ethical agenda that helps students to build their commitment to sustainability.

Learning about environmental ethics and social engagement would help students to engage with the environment and their social community and to develop a necessary *"sense of connection" (Wright 2003, p104)*. This is the basis for engaging the community, clients and rest of the team with the sustainable agenda, which also depends on effective communication and leadership skills. Interestingly, recent studies on education reached similar conclusions. Chen and Pitts (2006) found that although architects demonstrated a general awareness of sustainability, it had so far made limited impact on their lifestyles and therefore on their design options, while Sassi (2006) places the engagement of individuals' attitudes and lifestyles with sustainability as an essential part of the rationale of a new Master course on Sustainable Design.

It is important for students to leave the classroom for some periods and engage with their community; looking at local materials, climatic conditions, natural resources, ways of living, etc. and even being able to build small buildings for their community based on sustainability criteria that would definitely help to boost their commitment. There are many examples of this kind of exercise that have even successfully overcome time constraints in architectural education.

In addition to environmental ethics and social engagement, the development of an analytical attitude is necessary to understand and question current examples of sustainable architectural design and their relationship with their socio-cultural contexts.

### *2.2 Explicit knowledge*

The development of explicit knowledge is probably the most common approach to the inclusion of sustainability in education due to the fact that it is easy to include specific aspects in existing courses without altering the overall curriculum. It is common to find environmental sustainability issues included in the technology courses, as a block within the curriculum. However, this model proposes that this knowledge should not be confined to the technology courses and has to be integrated into the design studio and hopefully into all areas of

the curriculum. There is no easy strategy to achieve this aim, but the general criteria should be to introduce principles and strategies of sustainable design in the design studio from the outset and throughout the years of education.

The model includes the development of explicit knowledge in the form of principles and strategies of sustainable design, which have proved to be valuable in the generation of the initial design idea due to its synthetic nature that helps to face the velocity of the first stages of the design process.

Knowledge in architectural sciences (or building physics) is necessary for understanding the scientific basis of sustainable architecture which helps the students to anticipate any changes in the situation, such as a different climatic context or building type.

### *2.3 Tacit knowledge*

The development of tacit knowledge is probably the most difficult area to define in terms of concrete actions, as all the educational experience that the students undergo helps to build their tacit knowledge. This work identifies critical appraisal and quantitative analysis of case studies and the students' own design projects as a specific source of tacit knowledge distinct from the explicit or theoretical knowledge they find in books. The case studies could vary widely, from vernacular to high-tech, and from historical to contemporary buildings.

The choice of vernacular or historical cases is very important in reinforcing the environmental and cultural contexts, understanding that sustainability is neither totally new nor entirely technical. There is great opportunity for generating a better understanding of environmental issues by analysing their application in simple buildings that were designed with locally available materials before the time of cheap and abundant energy. Contemporary cases might help to identify the state of the art of sustainable architecture and ideas for future development. Following the idea of fully integrating sustainability into the architecture curriculum, the critical appraisal of case studies from an environmental perspective could be included in history and theory courses by engaging academics in these issues. It is crucial for students to examine these cases from a critical perspective in order to develop their own sustainability agenda, moving away from the idea of simply applying principles and strategies without careful reflection. The critical appraisal of case studies should help to build the students' "intuition" with a repertoire of images for recall, overcoming their initial lack of experience that is the basis of the intuitive dimension of the design process.

The important role that iconographies, derived from precedents, play in the generation of the initial idea would encourage the role of case studies as a way of generating knowledge. Although the idea of using iconic models can be contested on the basis that sustainable design is usually against the predominance of visual seduction in contemporary architecture, it is a fact that even architects who are deeply committed to sustainability refer to iconographies when designing. The point here is to look at examples that successfully combine sustainability and aesthetics. However, it is important to be cautious when using iconographies in education, as some elements of sustainability could be deliberately iconic, while having a limited impact on performance. It is also important to guide students in placing iconographies within a wider knowledge of the case study, understanding principles, strategies, context sensitiveness, climate, etc.

Quantitative analysis of case studies can act as a complement to the critical appraisal and can include the same wide diversity of buildings. Calculating solar penetration, daylighting or thermal performance might allow students to separate those strategies that have a positive effect from those that are not contributing to achieve the desired outcome. Quantitative analysis of their own projects might help students to understand the implications of certain design decisions and to explore different alternatives in an alternating process of intuition and analysis.

### *2.4 Skills*

Quantitative analysis is based on the development of skills in the use of analytical tools, which is extremely useful for understanding the principles of environmental sustainability. Some physical tools such as the heliodon, the artificial sky and the wind tunnel, as well as some user friendly softwares with graphic interfaces, are proving to be valuable educational tools in architecture. These simple tools might not be completely accurate in terms of quantitative results, and some of them will only provide qualitative information, but they help students to familiarize themselves with the essential concepts and the dynamic interaction of different variables during the limited time constraints of an architectural project in education.

Although the architects of the case studies do not generally use analytical tools, the scenario seems to be changing towards the increasing inclusion of user-friendly tools in architectural practice, while sophisticated tools will remain in the domain of expert consultants. Therefore, architectural education should consider the development of simple analytical skills, while engineering education or specialised training can cover skills for sophisticated analysis. The case studies also suggest that the visual interfaces of simple analytical tools have proved to play an important role as instruments for client persuasion. Therefore, the development of skills in the use of simple analytical tools is not only useful for quantitative analysis, but also for the development of the skills of social engagement.

It is important that architectural education provides a solid base of knowledge for the use of analytical tools because there is a risk of getting excited by the visual capabilities of the tools without understanding the implications of the results. In that respect, it is important for the students to know the basics of architectural sciences in order to be able to interpret the results and to compare them against benchmarks. In addition, knowledge of architectural sciences provides the skills of being able 'to speak the language of the engineers', i.e. to

be able to speak a scientific and technical language, which is useful for enhancing communication within interdisciplinary teams. The development of skills in interdisciplinary teamwork should also be an important task for architectural education. Project-based activities involving students from different disciplines grouped together might allow them to play the same roles they would assume in practice. The design studio is probably the best platform for these types of activities, where students can apply their different expertise in a particular project.

## 3. CONCLUSION

The model for integrating sustainable design in architectural education is holistic due to the complexity of the matter in practice. It proposes that the development of attitudes, knowledge and skills should bridge intuitive, analytical and social dimensions in order to tackle the uniqueness and complexity of the design process.

It is important to discuss criteria by means of which to include this framework of attitudes, knowledge and skills in the architecture curriculum. Wright (2003) argues that there are three approaches: the assumption that sustainability already permeates the curriculum by its very nature; the approach of expanding some existing courses on environmental technologies and systems; and the revision of the entire curriculum to achieve full integration. The holistic nature of the model suggests that it is necessary to fully integrate sustainability in the architecture curriculum, rather than including it as an add-on to each section. This integrated curriculum requires commitment to sustainability from the entire staff. Sustainability should be at the core of the theoretical, technological and studio based modules.

The main barrier to this idea would be the lack of commitment of the academics to sustainability, as well as their lack of knowledge in the field. In order to fully introduce these issues holistically into the architectural curriculum we probably need to wait for a new generation of academics who have been trained in sustainable design in their degree courses and are more engaged with sustainability. For the moment, it would be down to each school of architecture to determine their next stage of achievement; for some schools it would be enough to just permeate the technology courses—and possibly the design studio courses—as a first step; while others would be in a position to develop a new curriculum that deals with all the dimensions of the holistic model, with commitment from the academic staff and motivation from the students.

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