Evaluation Report for the CETL-D Funded Project 'A Student's Guide to the Environmental Use of Glass in Buildings'

Background

This project emerged from the interdisciplinary research on sustainability that I am pursuing within the Department of Architecture and Design, itself the outcome of work undertaken by myself (a physicist) and Mike McEvoy (an architect) whilst previously at the Universities of Westminster and Cambridge.
Glass has been the most inspiring of materials for modern architecture. Much of the quality of contemporary design is derived from the extensive use of glass. As glass production processes developed through the 20th c. so did the exploitation of transparency, and the dissolving of the distinction between indoors and outdoors, characteristics that have been central to the concept of modernity.

Now however legislation to restrict the use of energy and emissions of carbon dioxide are calling into question the large scale use of glass. In winter 25% of a building's heat is lost through its windows and 50% of carbon emissions are the result of the operational energy of buildings.

We therefore proposed a visual explanation for students of the issues involved within this debate. Using the striking images we can produce using Computational Fluid Dynamics and thermographic photography, both of which are a part of our usual research, we could explain heat and ventilation air flows through and around glazing, and surrounding construction.

Building physics can often seem abstract and irrelevant to architecture students, and discourage interest in the operational, rather than purely aesthetic, aspects of architecture. But the pressure that is now driving the agenda for building requires a sophisticated understanding of environmental questions. The use of graphic techniques both to display existing building performance and to simulate the dynamic aspects of energy flows, presents an intriguing way for this understanding to be achieved.

The specific aims of the project were:

To begin to assess how the use of advanced computational and experimental techniques could be used to improve architectural student understanding of buildings at a more fundamental level. We attempt to achieve this in two fundamental ways:

- By exposing the student to the relationships between design and their invisible implications, they are abtter placed in future to interact with buildings in a more fundamental way, which is a threshold concept. This threshold concept can follow them through their education and allow them to bring a better approach to many problems found in built environment whether it relates to the specific technologies presented here nor not.
- By giving the students a better appreciation of how buildings actually function they become less reliant on troublesome knowledge such as U-value, which abstracts the physics of buildings and masks these fundamental relationships. Pure adherence to numerical formula can and does result in legal buildings, but cannot on their own deliver environmentally well designed buildings that rely on subtleties in these core

relationships between heat, air and light to create desirable and energy efficient spaces.

These aims and techniques are not restricted to windows or buildings specifically but could be used in any discipline where the interaction of the physical world is of importance. Thermographic imaging of textiles and human bodies can give great insight into appropriate fabrics and their positioning to achieve specific clothing functions, use of CFD can give insight into how art work can respond thermally to an environment to allow a sense of temperature to become part of the experience.

In terms of this specific project further aims included:

To analyse with these techniques the evolution of glazing technologies used in buildings.

To analyse with these techniques case study buildings that have used glass as an important facade component.

To create a website that includes contextual information on different types of glazing, techniques used, analysis of glazing and case study types, and interactivity via VRML and Q&A sections.

To produce a handbook to disseminate through the website and directly to architecture schools that summarises and advertises the project.

To produce a cd-rom to allow students to experience the project even if they are off-line.

To send the handbook and cd-rom to architecture schools and publicise the web-site as widely as possible.

What happened

Computational Fluid Dynamics (CFD) was one of the chosen analysis techniques and this software was purchased before the beginning of the project.CFD analysis offers unprecedented levels of insight into the physical phenomena of heat and mass flow, but also requires considerable technical skill to be able to generate valid results. Many of the window designs under test required two fluid zones containing disparate baseline buoyancy conditions, and required experimental features of the software to model effectively. This additional phase subsequently took longer than expected but the general methodology was determined by the beginning of 2008.

From the beginning of the project discussions began regarding which case study buildings could be modelled from the information held at the RIBA library, but due to copyright and other issues detailed information on all the chosen buildings was not available so the RIBA archive was visited multiple times and hand drawings of the buildings they did have were made.

The general methodology of the website was then settled upon, but to deliver on this methodology a separate web space area had to be set up for the project as the CETL-D web templates were not flexible enough to achieve our aims. This methodology consists of a number of sections broken down by distinct phases in the learning experience, in this case:

- Description of the project itself

- Sections pertaining to the different ages of glass
- Case study section
- Interactivity section

Each of the these main sections had similar sections including an introduction, CFD, thermographic and conclusive sections to form a consistent pathway through the learning material. Originally it was envisaged that the pages would be available through a matrix with main section axis running along the top of the page and the secondary section axis running down the side. This is however time consuming to implement to html so a simple system was implemented whereby the main sections are represented along the top with drop down menus to represent the sub-sections. This appears to work quite well.
The site structure first takes the student through the principles that the site will later discuss and apply. A history of glazing is presented first so that the student has the temporal and technological context within which the development of glass has taken place. The two analysis techniques (CFD and thermography) are then presented so that the student is better placed to interpret the results and appreciate the validity of such techniques.
The phases of glass development are then presented in sequence from 'pre-industrial' through 'industrial', 'modern' to 'future'. The characteristics and history of each glazing type is discussed followed by an analysis of each glazing thermographically and with CFD to highlight some of the heat and airflow movements of these designs. Each section ends with a short conclusion to some up the section.

Next comes the case studies that are, after a contextual history section, analysed again thermographically and with CFD so that the performance of these iconic buildings can be assessed.
Finally there is an interactivity section featuring VRML models of some CFD windows and results that allows the student to pan zoom and rotate the models. There are however two limitations to this technique:

- A plug-in is required that needs to be downloaded for the files to be visible, which requires some extra effort on the part of the user.
- The VRML models produced by the ANSYS CFD software is not compatible with any freely available VRML viewer on Mac OSX and cannot normally therefore be viewed on macs.

There is currently no widely available browser viewing technology (like flash) that can interact with 3D models in the way envisaged here. Flash movies that can play a sequence of images cued by mouse movements is possible but was beyond the scope of this project, and is limited to simply playing the uploaded images. New technologies form Adobe (Adobe 3D) may make this possible in the near future and future projects should investigate these avenues if considering dynamic web content.

The website was released to staff and students at the School of Architecture & Design to generate feedback on the site which led to some changes to the navigational structure of the site. The address of the site is http://cetld2.brighton.ac.uk/enviro-glazing/home.htm.

Images from the sampling and survey work of the project were compiled along with public domain images (NASA), university credited images (Lawrence Berkeley National Laboratory) with written permission, and Wikipedia images under the stated terms and conditions. All image copyright issues have therefore been resolved. Images taken for the project are stated as being copyright the author, and can be used for educational purposes.

With the website compiled and on-line the handbook was written which acts as a summary of the website and the methodology and 50 copies have been given to RIBA to be sent out to Architecture Schools by Jane Oldfield of the RIBA Library. With each a cd-rom has been

produced with the web pages on so that students can navigate through the site whilst off-line. A flyer has also been produced and sent to RIBA for wider dissemination.

The project has under spent on the publication of materials as the focus of the project was shifted from printed to on-line output. The project was presented via a pod at the Deeds on September 19th, 20th & 21st. A paper was written for the University Pedagogic Research Conference: Enhancing higher education through research which was held on Friday 23rd January, 2009 but was not accepted so there is an under spend on conference travel and registration.

A combination of factors including personal injury, more investment in time in the project than originally envisaged and schedule conflicts with other research projects has led to the project as a whole concluding in February '09 as opposed to October '08.

Lessons learnt

The project has achieved its broad aims and objectives and has begun to investigate and implement environmental visualisation in an architectural teaching context and has received positive feedback. Some factors have however come to light that need further thought and development.

The process and techniques employed here lend themselves extremely well to a iterative approach that reacts to student design choices, as this helps the relationships explored here to embed themselves in the student's mind. This level of interaction is complex, if not currently impossible to achieve via a web interface however. Although elements of interactivity exist in the site as much as possible, the ability for students to adjust or create forms that can then be analysed and displayed with the experimental and computational techniques used here would require significant, but valuable, further work. A very large database of already completed scenarios, covering a number of topics, that a student can navigate through at their own pace and following their own interests may go some way to achieve this. In terms of CFD it is possible for forms to be created or selected and then sent to a server for solution and display, but this raises issues of compute time and the nuances of achieving results from CFD, especially without hands on guidance. The existing interactivity of the site could be further enhanced by use of flash videos that may change for example the value of iso-contours, or outside temperature with movements of the mouse so that a more manipulative view of existing results can be arrived at. Preliminary investigations of this indicated that this could be achieved with JavaScript and flash creation software.

It is also important in a project of modest scale to not engage in too many disparate activities that each require significant preparatory work. This can lead to over runs in the amount of time required to achieve the outcomes that are difficult to predict. In this specific case achieving satisfactory results in the creation of web pages, use of simulations and generation of sufficient technical building details was very challenging within the time scales laid down, and a more streamlined and focused project would have helped in this regard.

Research outcomes

The project has progressed the relationship between the author's subject discipline, and the teaching and learning in an architectural context and opens up new areas of investigation into the visual dialogue that can be created between disciplines to enhance the learning experience. The context within which architectural education occurs is ever broadening with environmental issues especially taking on a new prominence. The number and range of tools available to architects is similarly expanding with digital techniques in particular evolving at some speed. These contexts and their associated tools are increasingly in areas

associated with other disciplines, but imparting detailed knowledge of other disciplines is beyond the remit of architectural or any other teaching. At the same time tools that were specifically routed within other disciplines, requiring an expert in that field to operate effectively, are also changing becoming simpler to use and based on simplifying assumptions that have shown to be appropriate for specific situations. A good example of this is EcoTect which is built by architects for architects, but deals with the simulation of physical phenomena associated with the building physics realm. It is within the narrowing space between these two contexts that this project resides, and attempts to straddle. This project has progressed the use these tools' visual language to teach core relevant concepts associated with another discipline. This is especially relevant to architectural education which is already strong in the interpretation of visual language.

Evaluating the benefits

The beneficiaries of this project are primarily architectural students, educators, the School of Architecture & Design and the wider architectural profession.
Student's now have an on-line resource that:

- Gives a summarised history of glazing, and the technological and environmental drivers behind its evolution.
- Teaches the principles behind some common techniques used to analyse the performance of buildings.
- Shows how these techniques can be applied to, in this case, glazing.
- Demonstrates how the use of these tools can elucidate the thermo-physical implications of glazing designs.
- Visually expresses the relationships between visible design and invisible performance.
- Tests whether these relationships have been understood by encouraging the student to make conclusions from the results presented.

Educators now have an on-line resource that:

- Demonstrates the use of advanced visual techniques as a pedagogic tool.
- Provides a framework for further similar work in similar or other fields.
- Provides a resource than can be used int heir own teaching context.

The School of Architecture & Design now has

- An infrastructure in place to practice the principles used here in hands-on teaching.
- Experience in the use of these tools and their pedagogic potential.
- A new way of broadening the student learning experience.

In general the architectural profession has a resource to find out about two of the tools that may not be used by themselves, but is often used by environmental consultants, and will aid them in the interpretation of results of these analyses.

How you have met the selected CETLD themes

This project supported the aim of 'Interdisciplinarity in design education / innovative pedagogic research and evaluation' chiefly through the use of techniques associated with science and engineering in the pursuit of architectural understanding. The project is strong in cross-disciplinarity and uses its accessible visual nature as the connection between the science and design fields. It takes the specialist science knowledge of the author, which has been built up over many years, and distils and relates it in a form that students can understand and utilise and in this way has parallels to the work carried out at York University

where academics write papers on their specialist subjects in a simplified form for dissemination to their students. In this regard the project has relevance to almost anyone with a specialised knowledge base working in educational environments, as it attempts to use a visual, accessible language to relate ideas. If the ideas can be presented in a suitably engaging way many of the barriers that exist between students and teachers could be removed or lessened.
Ultimately the project is devoted to sustainability, by marrying environment and design, and creating a greater understanding of the influence of each on the other, and as such will be transferable to a wider audience throughout UK architecture schools. By sending the handbook and cd-rom to other schools it is hoped that a dialogue will be created with use of the materials created within the learning context at other institutions.

Dissemination

As well as the public website, which has been released to Brighton students via student central, the handbook and cd-rom are being sent to every architecture school in the country. In addition the website is being advertised via e-bulletin to the 10,000 RIBA student members and is to have a space on the RIBA research wiki. A short article will also appear in the RIBA journal to advertise the project to the wider architectural community.
The project was also presented at the DEEDS conference to a wider audience interested in sustainability and design.

Next Steps

The author plans to use some of the principles behind this project to augment architectural teaching at Brighton's School of Architecture and Design next academic year.
By engaging students directly with CFD and taking them through the process of analysis and evaluation of issues revealed by their design studios, the relationship between design and environment (cause and effect) will be further strengthened. This process will begin with tutorials and simple scenarios to highlight broad physical phenomena and end with the student undertaking work specific to them and their needs, albeit with guidance.
Also the use of thermographic images will be expanded to create panoramas of sites relevant to their design studios so that the thermal environment in which their schemes exist can be better described. This in turn is planned to lead on to work with high dynamic range (HDR) imagery to achieve the same goal with visible radiation (lighting) environments.
Further additions to the website are planned either with enhanced interactivity with flash, or addition of further content that can either relate to the same broad area of study (e.g. ventilation) or can begin to investigate its use in other disciplines (the use of thermography in the 'Fashion & Textiles' is of particular interest)