

## **ECOTECT: Environmental Prediction in Architectural Education**

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**Abstract.** This paper evaluates the integration and use of ECOTECT, an environmental prediction software package into teaching within the authors' school of architecture.

ECOTECT is relatively unique amongst performance analysis tools in that it is aimed primarily at architects and is intended for use during the earliest, most conceptual stages of design. It integrates a relatively simple and intuitive 3D modeling interface with a range of analysis functions

**Keywords:** Environmental Design; Predication; Architecture; Integration; Software;

### **The environmental prediction course**

The Welsh School of Architecture has, for a number of years, placed a heavy emphasis on the appropriate consideration of environmental design issues within project work. Students are asked to evaluate the environmental strategies of their designs through the creation of a technical report submitted alongside every design project. Whilst these reports are assessed as part of the students' building technology lecture course, linking them to specific design projects ensures greater integration between the lecture course and the design studio, helping to ensure that environmental considerations are taken into account during the design process.

During the second year of the undergraduate course, the school holds an environmental prediction week for all students. This occurs at a point during a major design project and allows the students to evaluate the environmental conditions within their schemes and to amend their designs where necessary. The principal aims of the week are to give students an awareness of the tools that are available and to make them aware that environmental predication is not something that is done at the end of a project but rather as something that is fed into the design process. Students are expected to analyse a key space within their schemes (often a classroom in a school) in terms of daylighting, acoustics and energy use. Traditionally acoustics and energy use have been predicted by longhand calculation, whereas daylighting levels and qualities are analysed through the creation of simple cardboard models placed in an artificial sky and heliodon. As the analysis progressed, students were able to make direct modifications to their models to improve performance. In recent years the value of computers as predictors of building performance has also been recognised.

Students were asked to build a version of their models in CAD as well as cardboard. They were then able to use the CAD package to simulate positions of shadows within the space using a simple raytraced light and rendering package. The computer techniques were kept deliberately simple, as many of the students had very little experience of CAD. They were then asked to compare the results from the computer to the cardboard model and thus were able to gain an understanding of the key benefits and differences of each technique. Generally the results were favourable, although the computer models were often less accurate than the cardboard model, due to the limitations of the rendering algorithm. Nevertheless, students recognised that the computer techniques provided a valuable "rule of thumb" to their designs.

In order to address the “accuracy” issue reconsideration has been given to the computer software during the prediction week. It was necessary to find software that was simple to use, quick to learn and produced reasonably accurate results that the students would be confident in building into their designs. Hanna (1997) looks at some of the previous options for evaluating lighting design. Once students had modelled their buildings then they could rapidly make amendments to suit environmental conditions. The choice was made to use the ECOTECT software developed by one of the authors (<http://www.squ1.com/>: June 2001). This was used for the first time during the 2000-2001 academic year and an evaluation of the software and its integration into the student’s learning experience was carried out. The software was used primarily to evaluate daylight penetration and quality at a various times of the year and additionally to calculate reverberation times.

## ECOTECT

The ECOTECT software is relatively unique amongst performance analysis tools in that it is aimed primarily at architects and is intended for use during the earliest, most conceptual stages of design. It integrates a relatively simple and intuitive 3D modelling interface with a range of analysis functions. These include: overshadowing and solar reflection; sun penetration and shading device design; solar access and photovoltaic/heat collection; hourly thermal comfort and monthly space loads; natural and artificial lighting levels; acoustic reflections and reverberation times; project cost and environmental impact.

The most significant feature of ECOTECT is its interactive approach to performance analysis. Students are able to select different surface materials and very quickly compare the resulting changes to internal lighting levels, reverberation times, monthly heat loads and hourly internal temperatures at different times of the year. New windows can be added in order to see their effect on daylighting, thermal response and overall building costs.

As the complexity of the model increases, it can also be exported to a range of application-specific tools for more detailed analysis. Formats currently supported include: the RADIANCE radiosity-based lighting simulation package from Lawrence Berkley Laboratories; VRML for interactive 3D visualisation; the DOE-2 and EnergyPlus thermal simulation tools from the US Department of Energy and a range of other applications such as POV-Ray, a freeware raytracing-based rendering tool.

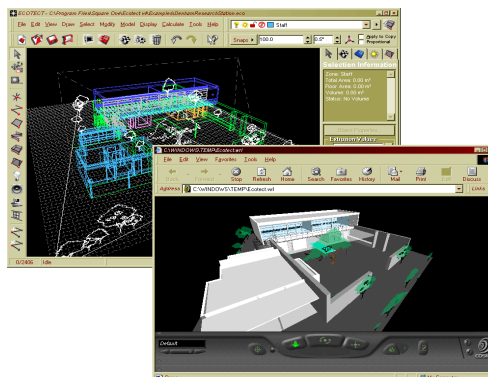


Figure 1. An ECOTECT model displayed as a VRML scene within a web browser for an interactive walk-through.

### *Computer-Based Sketching*

One of the major challenges in the development of ECOTECT was to produce an interface within which geometric modelling could be as simple, loose and disposable as a traditional hand sketch, yet still be used for both general and detailed analysis. This required a departure from traditional CAD environments which tend to concentrate on the drawing process rather than modelling - the lines that define an element only provide visual clues as to its architectural function. In ECOTECT, a relational modelling system is used in which the role of each element and its relationship to others is automatically derived from the way it is created. This basically means deriving the geometry and type of one element from the geometry and type of another, and storing the rules used. If the parameters of these rules are subsequently changed, or the parent element moved, the geometry of the child can be automatically updated.

To define a room, for example, the student can simply draw the floor plan and the walls and ceiling are automatically extruded. The software can reasonably assume these architectural roles for each element thus created and implicitly define them as such, assigning default material properties for each type based on the previously defined preferences of the user or this particular model. If the student later repositions one of the corners of the room, it is highly likely that they would also want the extruded walls and ceiling to adjust accordingly, as well as any windows or doors contained within the walls.

Automatically deriving element types and generating geometric relationships can significantly reduce data entry time and substantially increase the editability of the model. Obviously there are times when these may get in the way of the user, however it is a very simple matter to reassign and unlink objects.

### *Progressive Data Input*

In ECOTECT, all calculations are structured around a full set of basic assumptions and default values which can be changed at any time. Inexperienced users, or those requiring a quick result, need only specify whatever level of information they have at the time. As the design is gradually resolved more detailed information is added to the model, making the results progressively more accurate. This makes the process of modelling far more responsive.

There are, of course, issues relating to the validity of results based on default values. However, the same limitations are true of simplified manual and rule-of-thumb methods which are well understood and accounted for by most practitioners. Where accurate results are more critical, more information is provided. This allows the *designer* to control both the effort and accuracy required for a result, not the application developer.

### *Visual Feedback*

The very nature of the architectural design process is visual. This is especially true of the early stages of design where the building form itself is still being established. In addition to simply displaying results, ECOTECT attempts to relate the analysis directly back to the geometry. This is relatively simple in the case of solar and lighting calculation, however it is not always possible as some results can only be displayed as a graph. Where possible, however, graphs are displayed as separate

interactive windows that automatically update to reflect changes in the model. In some cases, changes in the graph can also automatically effect changes in the model.

Many building analysis tools also provide very little visual feedback during calculations. This means that the process being undertaken is essentially hidden from the student, who has to trust in the fact that what is being modelled is correct. Mistakes in modeling that are not immediately visually apparent must be determined from a detailed examination of any output.

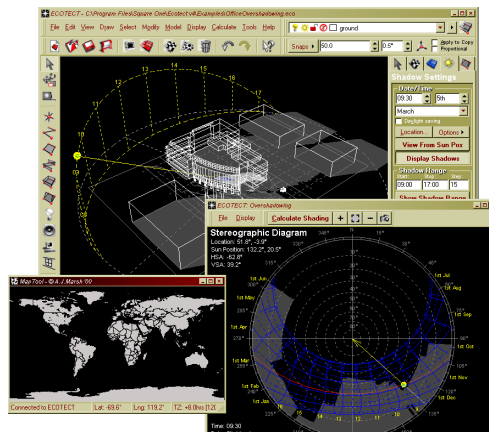


Figure 3 Display showing world location, a 3D model with shadows from the current sun position and a 2D sun-path diagram with overshadowing patches for the selected point. Interacting in any one window automatically updates the results shown in the others.

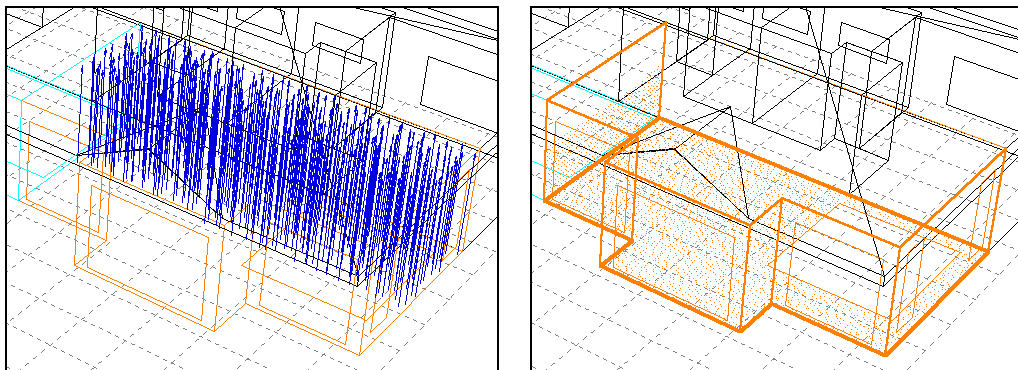


Figure 3 Examples of visual feedback during volume and inter-zonal adjacency calculations. The image on the left shows the arrows used to determine the volume of a complex space whereas the image on the right shows areas of overlapping surfaces being dotted in by the software

Whilst the majority of calculations are not inherently visual, there are techniques that can be used to make them more so. For example, when using sampling or ray-tracing techniques, it is a simple matter for ECOTECT to display each point or ray as it is generated and tested. This acts to provide an indication of how the calculation is progressing as well as allowing the user to identify possible problems with the model by observing anomalies in the display. Such techniques have been implemented during surface area, volume, daylighting and acoustic calculations.

## Evaluation

The evaluation was carried out by the administration of student questionnaire and casual conversations with the student group. The questionnaire comprised of 17 fixed response questions related to ECOTECT, to the module as a whole and to how the two related to the student's design project, and architectural experience. The students also had an opportunity to complete a written section of the questionnaire where they could identify the benefits and limitations of ECOTECT. 43 students responded to the questionnaire.

### *Integration of ECOTECT into the learning experience*

The students were asked whether the environmental prediction week had contributed towards their general understanding of architecture. This question was asked specifically to determine the students' perception as to whether the contents of the week appeared to be integrated with the remainder of the student's learning experience. On the whole 85% of respondents either agreed or strongly agreed that this was the case. The lack of integration between technology and the remainder of architectural education is a concern of many architectural educators but it would appear that the placement of environmental design within a block course related to a current design project is beneficial. The results also suggest that the students felt that there was more to the week than simply learning to use the software.

The integration question was supplemented by a question asking whether ECOTECT specifically, proved to be a useful contributor to the development of the student's design project. The responses to this question are summarised in figure 4. The results imply that the majority of students found ECOTECT a useful contributor to their design process and this is backed up by evidence from students' submitted design work.

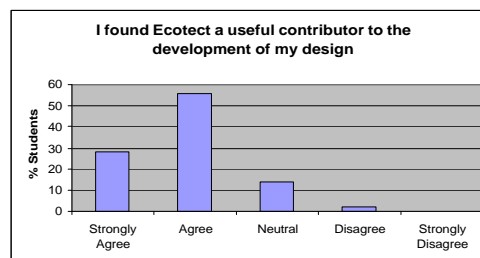


Figure 4 - How ECOTECT contributed to student design work.

### *Comparison of results with student's intuitive judgements*

During the environmental prediction week, a number of students expressed concern that the results generated by ECOTECT were different than they had personally imagined. A common concern was why at certain times of the year the light was not falling as they expected. Further investigation revealed that the students' heuristic judgement of how their building might perform was sometimes naive and this had only been realised through the use of environmental modelling. Data from the questionnaire suggested that over a third of students found that the results generated from ECOTECT differed from their how they had imagined. There was concern amongst some lecturers that the use of ECOTECT could lead to students not developing their own intuitive judgements of the environmental conditions within their building and becoming too reliant on the software. It was also observed that in

some cases students were incorrectly modeling some of their geometry, and consequently ECOTECT produced an inaccurate result. It is important that students understand the principles behind ECOTECT's calculations so that they can make estimates, and detect where errors might be occurring. Generally the students found that the results generated by ECOTECT were not dissimilar to those generated by physical modeling.

#### *Perceived strengths and weaknesses of ECOTECT*

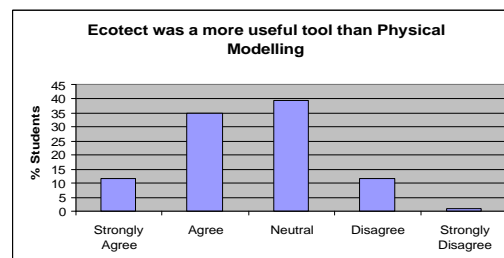
The students were asked to identify the key benefits and limitations. Most of the comments fell into clear groupings, which are shown in table 1.

*Table 1 perceived benefits and limitations of ECOTECT.*

<b>Benefits</b>	<b>Number of comments</b>	<b>Limitations</b>	<b>Number of comments</b>
Simplicity of modelling, intuitive interface	15	Modelling complex shapes (such as curved walls)	5
Speed	9	Lack of certain features (More preview options, wall thickness, materiality options),	5
Ease of interpretation of results	9	Stability (crashes)	2
Use in informing design	7	Lack of personal understanding on how to use the software	2
Others (Accuracy, specific features, online help)	6		

The simple, intuitive interface appeared to be the key benefit to the student, although a number complained about difficulties of creating complex geometries, such as placing windows into curved walls. Responses to a fixed response question on the limitations of ECOTECT suggested that approximately a third of the students felt constrained by the limitations of the software, although to some extent this may be a reflection on some students lack of understanding of how to use the package. It should be noted that complex geometries could be imported from another CAD package although in many cases developing a better understanding of some of the modelling 'tricks' within ECOTECT and some degree of simplification (for instance reducing curved walls to a series of facets) was a more effective solution.

As mentioned earlier, the students were asked to analyse their designs in ECOTECT as well as in the school's artificial sky and heledon. The students were then asked whether they found ECOTECT the more useful tool. The results are shown in figure 5. On the whole students did find the ECOTECT more useful, probably because of the speed and ease of use.



*Figure 5 - Students preferences for ECOTECT and physical modeling.*

Finally, when asked whether they would use ECOTECT to help with future designs, 95% of the respondents either agreed or strongly agreed (33%) that they would.

## **Conclusions**

For many years teachers of architecture and environmental design have been looking for simple, and intuitive mechanisms to enable students to evaluate and assess their designs. ECOTECH provides a simple to use and appropriate mechanism for this. With appropriate integration into courses ECOTECH can prove a potential benefit for improving student understanding of concepts that often remain in the domain of lecture theatre theory so that they can be applied to student design work as a whole.

## **References**

Hanna, R. (1996) A computer based approach to teaching daylighting at the early design stages, in Ekholm et al (eds) Education for Practice, the proceedings of the 14<sup>th</sup> ECAADE conference. Sweden:,Lund University, pp181-190