Education in Environmental Construction at the University of Plymouth: the Eco-House Project

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ABSTRACT: The Environmental Building Group at the University of Plymouth educates students towards accredited degrees in Building Surveying and the Environment, Environmental Construction Surveying and Construction Management and the Environment; close links are in place with the local School of Architecture. This paper describes the Eco-House Project that is part of the initial Domestic Construction Technology course. The project is designed to develop the students' creative and team working skills, while deepening and applying their technical knowledge. Groups are formed that consist of students with different backgrounds, i.e. working towards degrees in surveying, construction management or architectural technology. These groups are then asked to develop a sustainable building project proposal for a real life site; tasks include measured site survey, definition of the group's understanding of an eco-house, design development and representation (including CAD and scale models), and analysis efforts to underpin design decisions. The final results of all groups are brought together in an exhibition where each group presents its outcomes to an assessment panel that includes University staff and external visitors.

Keywords: environmental building, education, design

1. INTRODUCTION

The Environmental Building Group within the School of Engineering at the University of Plymouth (Plymouth, United Kingdom) offers undergraduate courses in Building Surveying and the Environment, Environmental Construction Surveying, and Construction Management and the Environment. As part of the first year, students following these honors degree courses take an initial module on Domestic Building Construction Technology (coded ENBS-111). This course is offered as an optional module for students in Architectural Technology at the School of Architecture.

The ENBS-111 Domestic Building Construction Technology Module introduces the students to the basics of building technology encountered in housing and housing construction. Topics covered in the module include: building functions, technical drawing, building construction process, introduction to services, HVAC basics, building regulations, and selected lectures on specific elements of the building, such as foundations, external and party walls, roofing, stairs, and paintwork. The module is one of a series given in the first year, others include construction materials, mathematics, building science and technology, building law and site surveying. Typical books used on the module include Riley and Howard's House Construction [1] and Barry's Introduction to Construction of Buildings [2]. ENBS-111 is a full year module, covering both the first and second term. In the first term the emphasis is on general issues and mainstream building technology. In the second term students are introduced to such environmental issues as energy efficiency, material use, and water conservation. Moreover, the second term takes a different approach to teaching, shifting away from classical teaching/lecturing towards activities that require a higher student activity. Student numbers on ENBS-111 currently are in the magnitude of 50 to 60 students per year. Apart from academic teaching activities, the module also includes a number of site visits to allow the students a close-up view of real construction practice.

The Eco-House Project is the main coursework in ENBS-111, covering most of the second term, which runs from January to the end of May. It is a design project as encountered in most building/architectural studies. As the module on Domestic Building Construction Technology fits in with degree courses that all have a specific environmental focus, the focus here is on environmentally friendly housing. The project intends to help the students develop their creative and team working skills, while deepening and applying the theoretical and technical knowledge acquired in the first term of both ENBS-111 and other modules.

2. PROJECT ASSIGNMENT

2.1. General framework

At the start of the Eco-House Project students obtain general instructions that specify their general learning goals, assessed skills, project tasks, and expected outcomes of the project. They also are informed of the assessment criteria and procedure.

Students are assigned to groups by the lecturers. This ensures a good mix of the varied backgrounds, ideally having each group bringing together students in architectural technology, environmental surveying, building surveying and construction management. Group assignments are non-negotiable, forcing the students to adapt a professional attitude and helping them to develop their team-working skills.

The learning goals in this project relate to the development of the ability to gather, process and integrate theoretical knowledge into a real-life design problem as encountered in practice. Furthermore, students learn about project development in a team context and start an ongoing process of peer review and self-reflection/evaluation.

Assessed skills include specific professional competencies such as briefing, surveying, designing and detailing, and understanding of construction technology, as well as more general skills concerning group work, model building and presentations.

Regarding the actual project tasks, students are asked to research the issue of environmental building, using various traditonal and electronic learning resources to investigate 'eco-housing', and are asked to define the group's own design goals. They are provided with an initial site plan, to develop into a full site plan by means of desk-based research and a measured survey on site. They then develop conceptual designs for the site and present those to the module leaders for feedback. From here there is a continuous process of design development, feedback and design improvement, leading up towards final project outcomes. At the end of the project each group is asked to design and realise a presentation of their results. This is displayed in an exhibition, where each group presents it's outcomes to an assessment panel.

The outcomes expected from the project are as follows:

- site appraisal report
- accurate survey drawings
- description of group design principles
- logbook describing the progress of the Eco-House Project
- site drawing in 1:200 or 1:500 scale
- masterplan for the site in 1:200 or 1:500 scale
- floor plans in 1:100 scale.
- section in 1:100 scale.
- elevations in 1:100 scale.
- drawings of construction details in 1:5 scale
- evidence of analysis and calculations regarding choice of building materials
- evidence of analysis and calculations regarding choice of energy efficiency
- schematic services layout for electrical system
- schematic services layout for HVAC system
- scale model of the eco-house
- static, self-explanatory display
- oral presentation
- self evaluation statements of team effort and performance.
- self evaluation statements of individual effort and performance.

2.2. Specific 2005-2006 Project Brief

For the academic year of 2005-2006 a site has been selected in the heart of Plymouth City. This site, situated on Alma Road / Wake Street, previously held terraced houses which have been removed. The site has been vacant for some years. It is owned by Plymouth City Council, which is offering this plot for sale, to developers presenting a viable scheme. See figure 1.

The site is located within walking distance of Plymouth Railway Station, which offers students a good incentive to think about the way they treat transport issue to and from a housing development. Furthermore, the site is located in an area that has some complex social problems, creating a link to the social aspect of sustainable building.

Figure 1: Overview of the site used for the Eco-House Project 2005-2006 (Alma Road, Plymouth, United Kingdom)

For the eco-house design process students are reminded of the United Kingdom's pledge to reduce carbon emissions, and, in line with this, are required to develop an 'environmentally friendly' scheme for the site. This should include a master plan for the whole site, with the division of the land into building plots, access roads, parking spots and landscaping elements. Students also need to think about the viability of their project, which needs to meet all existing and appropriate planning and building regulations. Viability includes broad thoughts on funding issues and the type of development. It envisions that the students will make informed choices regarding commercial development versus social housing, housing density and similar issues. Within the overall masterplan each group then focuses on the detailed design of an individual building (hence the project name Eco-House). Depending on earlier choices this might be a detached house, terraced house, or an apartment in a larger building block.

3. TEAM WORK

In the academic year 2005-2006, the Eco-House Project was undertaken by thirteen groups, each consisting of four to five students. The students were briefed on the assignment before Christmas, and work on the project started in January. Each group is encouraged to form a coherent team and develop a relevant 'corporate' image, including a team name.

3.1. Design Principles

The teams were given free reign in defining their design objectives and focuses, within a realistic but environmentally friendly context. Different approaches emerged; while most teams adopted a straightforward mix of energy efficiency and material use, there were also groups that selected biomimicry or maximum material reuse strategy as lead principles.

3.2. Site survey

The students undertook a walkover and measured survey in January and February of 2006. The walkover survey allowed them to get familiar with the site in terms of vegetation, obstructions, terrain conditions, adjacent buildings and infrastructure, while the measured survey built upon the earlier visit and required them to get measurement data on site using total station electronic distance measuring devices (EDMs), site levels, prisms, tape measures and surveying staffs. See figure 2.

Figure 2: Students undertaking the measured survey of the Alma Road site.

3.3. Masterplanning

The City Council's planning documents suggest 26 dwellings be created on the plot. Most groups kept in line with this; however, other groups varied the densities. A number of groups opted to develop the site as student housing, arguing that the close proximity to the University of Plymouth and the railway station made this the optimal choice. One group decided to provide housing for elderly people, since this is an increasing part of the population and in line with social concerns. Others groups selected apartment blocks, semi-detached housing, or a mix of the two.

The site is located adjacent to Central Park. This saw two main responses: some groups decided that this provided enough green space opportunities for occupants, which allowed for intensive use of the site for other purposes; others decided to link up site and park, and have a substantial landscaping element on site. This element was closely reflected in the approach to the number of parking spots on the plot, and the role of the bus stop on Alma Road. Only one group decided to hide a large parking space by partly forming it underground. Three groups included a safe bus stop with a shelter on the main road, arguing that public transport would be the main means of transport for this area.

Landscaping elements included by several of the groups include ponds and connecting watercourses, and earth walls to keep the traffic noise from Alma Road out of the site. One group decided to turn the plot into a gated community, in order to prevent problems with the neighbourhood.

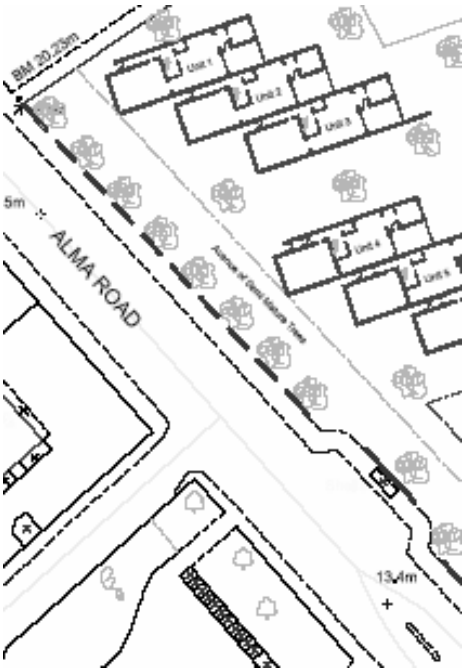

Figure 3: Part of a masterplan for the site, showing the bus bay and shelter on Alma Road by group H, the 'Ecological Housing Company'.

3.4. Building design and lay-out

The actual building design is supported by background lectures from University of Plymouth staff on topics such as energy efficiency and material

selection, as well as specific reading material, including Roaf *et al*.'s Ecohouse Design Guide [3] and Anderson *et al*.'s Green Guide to Specification [4]. However, even with this support, the actual design requires integration, creativity and a hands-on approach in order to come up with site-specific plans.

Actual housing designs varied widely, corresponding with the different design principles adopted by the different groups. Some examples are given to show both differences in design approach as well as different levels of design elaboration, taken from different stages of the building design.

Figure 4 shows initial sketches from the early stages of Group F, 'Beleaf', developing a building lay-out based on the outline form and veins of a leaf (see Figure 4a), and some initial concepts for the façade, which is to be based upon a honeycomb hexagonal grid (see figure 4b).

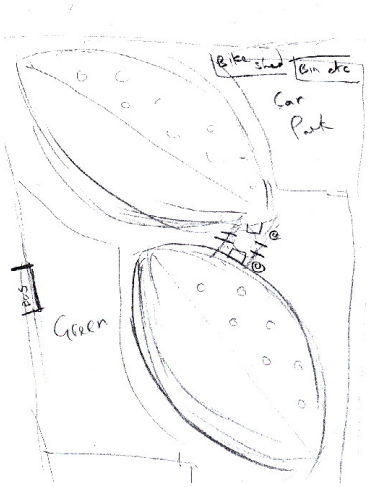

Figure 4a: Initial building plan concept by group F, 'Beleaf'

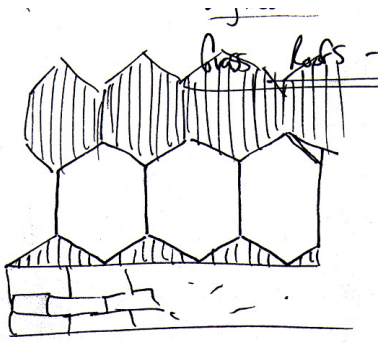

Figure 4b: Conceptual design stage building facade sketch by group F, 'Beleaf'

Many of the groups developed building designs consisting of an apartment block, often in an L-shape to create a semi-enclosed inner court, used for either landscaping, parking spaces or another sort of communal area. In line with adjacent buildings, most groups developed plans that included three stories. Access to the individual apartments is often by means of a south-facing atrium, that acts as a pre-heating device for ventilation air, a buffer zone against sound from Alma Road, and a winter garden or communal area.

At the other end of the spectrum, figure 5 shows final stage CAD drawings from group H, the 'Ecological Housing Company'. This group contains a mature student with experience in building design. The influence is clearly visible in an almost minimalistic approach to plan development, material selection and system choice, which may be in line with real-life market conditions and which is possibly a viable scheme for this site. Note the receding south-facing living rooms with large windows to maximise solar gain. See figures 5a and 5b.

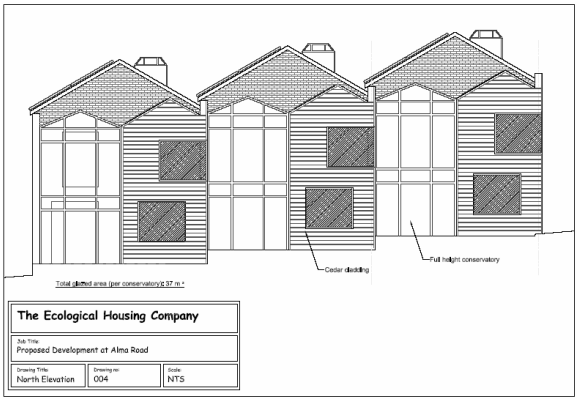

Figure 5a: Eco-house elevation drawing in CAD by group H, the 'Ecological Housing Company'.

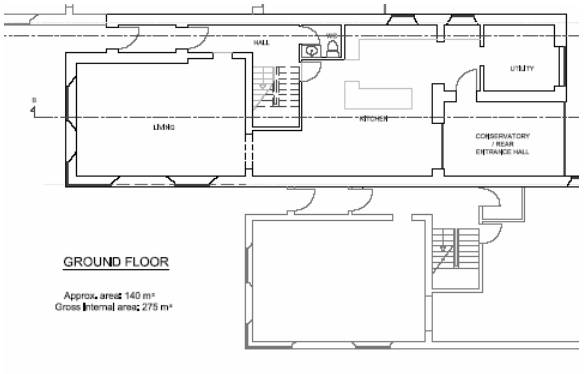

Figure 5b: Eco-house ground floor drawing in CAD by group H, the 'Ecological Housing Company'.

3.5. Energy Efficiency

Energy efficiency is one major design objective in all projects. As in real practice, approaches to achieve this objective vary wildly, from the use of highly insulating materials to specific systems such as photovoltaic arrays, ground source heat pumps, Trombe-walls, sunspaces and passive solar windows.

In order to prevent 'greenwash', students are asked to provide evidence of research on the systems

employed, as well as a decision matrix which demonstrates (a) the different systems that have been considered for the building (b) the criteria applied to system selection and (c) scores by the group, resulting in the final selection. While a first-year design exercise cannot allow for a full in-depth computational analysis of the contribution of specific systems, the decision matrix provides a good framework to structure internal group discussions and is an easy way of communicating the underlying efforts that are embedded in the final design.

3.6. Material Selection

The selection of environmentally friendly materials is another major design objective in all projects. Again, approaches vary wildly, from the reuse of bricks, timber frame structures, reuse of concrete, to insulation with sheep's wool.

Just as with energy systems, students are asked to provide evidence of research on the material selection process by means of a decision matrix showing alternatives considered and criteria used.

One group took material reuse to the extreme, and decided to construct their eco-house by means of reused sea containers. This reflects Plymouth's status as a major port, with easy access to containers and gives the building a clear relationship with it's location. Moreover, they considered containers to be the right size for their proposed use as student accommodation. Where needed, containers can be exchanged for new ones, allowing future upgrading of the building. A floorplan showing the layout of a container as student accommodation is shown in figure 6a.

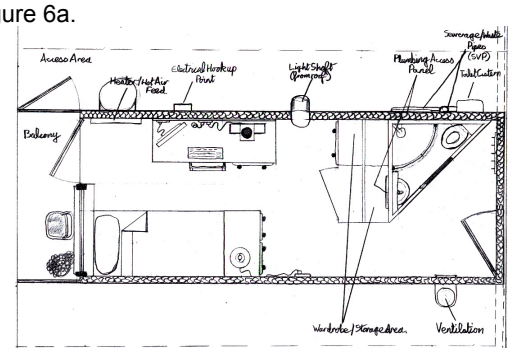

Figure 6a: Floorplan of a container, used as student accommodation by group D, 'Catalyst'.

In order to provide a comfortable internal climate and energy efficiency, the containers are positioned within a stack enclosed in a second skin. This prevents complex insulation processes within individual containers, and removes condensation risks. Extensive glazing is used to provide views out, passive solar gains, good levels of daylighting, noise protection, and an industrial image that fits the reuse concept. See figure 6b.

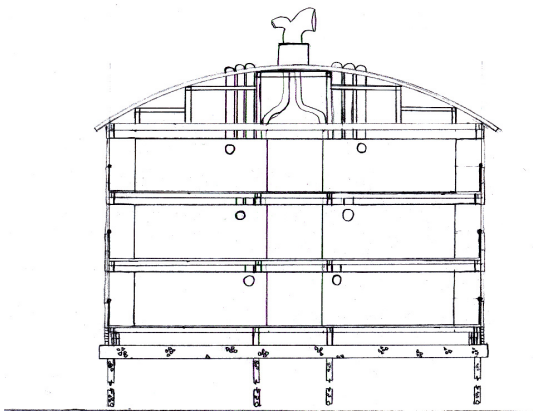

Figure 6b: Container stack, preliminary design drawing by group D, 'Catalyst'

3.7. Water efficiency measures

Water was not specifically targeted in the project brief. However, many groups did address this issue, providing different systems to slow down site run-off (green roofs, pond systems), grey water circuits, and rainwater collection and storage systems.

3.8. Final presentations

The final results of all groups were brought together in an exhibition where all 13 groups presented their outcomes to an assessment panel that included University staff and external visitors. Each group gave two oral presentations on their project, for two different assessment teams in a full-day event on the 23rd of May 2006. See figure 7. All teams passed; feedback from the externals as well as the academics joining in for the assessment was very positive.

Figure 7 **P**resentation of the Eco House Project

The assessment by external visitors is a pivotal element of the Eco House Project, which works in two directions. Students experience feedback from people working in real practice, preparing them for their future working environment and setting them appropriate benchmarks. The external visitors in turn, by participating in this assessment, are confronted with student work that is driven by sustainability

issues and academic thinking, which helps them to reflect on their current practice and ongoing developments in the field.

4. STUDENT FEEDBACK

Student response to the Eco House Project is very positive. For instance, in the Student Module Feedback Questionnaire (42 responses), 12 students list the project where asked to indicate what they liked most about the module overall. Student turnout and participation in meetings with the staff are generally good across the whole module.

In-class remarks, however, indicate that some of the surveying students struggle with the design element, and would prefer to leave this part to the architecture students. In response, it is beneficial for other professionals in the building industry to have hands-on design experience, since that will facilitate the communication with architects and may provide a different understanding of buildings 'as designed'.

5. CRITICAL REFLECTION ON THE ECO-HOUSE DESIGN PROJECT SET-UP

The Eco-House Project is a challenging assignment, enjoyed by most students undertaking it. Reflecting on the 2005-2006 assignment and results, the following remarks can be made:

- The students seem to benefit greatly from an "expected results checklist" as included in this years assignment, which provides them with a clear overview of what is required.
- The site used in 2005-2006 is more suitable for the design of larger building complexes, and less for individual houses. Selection of a site for 2006-2007 might be done in a way to encourage smaller scale projects.
- A regular problem with this kind of project is the assessment of groupwork in which some students rely on their colleagues for input and effort. This year a logbook has been introduced to ensure fair assessment. Even so, continuous attention is needed to minimise the risk of students not participating in assignment, helped, in part, by a formal peer review process at the end of the project.

6. CONCLUSION AND REMARKS

The Eco-House Project plays a pivotal role in the Domestic Construction Technology module. It brings together all techniques and systems covered in the lectures (from foundations to roofs, from architectural design to heating systems, from urban planning to construction details). Moreover, it requires the students to take an active, hands-on approach to all these elements, integrating them into one scheme and working on their interactions and relationships.

In terms of Environmental Building, the Eco House is a challenging project that requires students to field their own ideas on what is environmentally friendly, and how to realise dwellings that meet their own criteria. As such, the project is an important generator of critical thought and helps to equip the students with a critical attitude.

The 2006 Eco-House Project was a success in that all students passed their coursework. Moreover, the project was enjoyed by most of them, and the outcomes got positive feedback from both other acdemics as well as from the external assessors.

Finally, the Environmental Building Group of the University of Plymouth is participating in the Center of Exellence in Teaching and Learning focused on Education for Sustainable Development (CETL-ESD) at the University of Plymouth. The Eco-House Project and related spin-off provide an important basis for contribution of the group to the Center of Exellence.

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