An operational model for teaching low energy architecture

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Abstract:
Awareness of the need to integrate sustainability at all levels has recently been gaining momentum in education to meet pedagogical university policy, government and employers’ expectations. Within the school of the Built Environment at Northumbria University an integrated course delivery has been adopted for second year students.

This proposal intends to disseminate an operational model for integrating teaching and assessment between three modules which have traditionally been taught and assessed separately to achieve a low-energy house.

Introduction:
The concept of sustainable development long inherent in architecture has radically changed since the discovery of oil, air conditioning systems, artificial lighting and evolution in building materials after the industrial revolution. Several oil shocks and awareness of the human impact on climate led to the (Burton report) in 1987. To apply the principals of sustainable development, outlined in the report, architectural and architectural technology education need to highlight the need for the built environment to learn from lessons of the past while using technological achievements to sustain the needs of the present without compromising the needs of the future. Aided by a variety of interoperable software tools assessing how sustainability measures deliver low-energy architecture is achievable.

Previous research on integrating sustainability into an undergraduate engineering course (Carew and Mitchell 2002) called for the infusion of the engineering curriculum with sustainability learning. Szymkowia (2003) looked at the challenges facing this integration of sustainability within the French engineering schools and universities, in which the working group concluded that ‘there is a need to win acceptance for a project-based teaching methodology that would anchor the concept of sustainability to the real world, and would not allow it to turn into a merely rhetorical discipline. While using virtual reality tools to help students integrate sustainability measures was investigated by (Horne and Hamza, 2006) and (Ramasundaram et al, 2005) among others.

The context:
The Architectural technology course was developed in 1998 to respond to the growing need in the UK construction industry for professionals to interface between the design conceptual phase (architects) and the construction phase of buildings (various construction professionals). The main premise of the course delivery and module design is to respond to a triangle of influences from government policy, employers’ expectations, and the pedagogical expectations of higher education. In this case an understanding of those three influences is important to derive an integration methodology.
**Government Policy:**

The UK government is tightening regulations to achieve low-energy buildings. The government has strategic goals to reduce the built environment’s energy consumption and carbon emissions whether in existing or new built stock to meet the Kyoto Protocol targets. Any building work within the UK needs to comply with 13 parts of regulation that cover all aspects of construction and services provided. The UK government on the 6th of April 2006 had affected immediately compliance with the new Part L: Conservation of Fuel and Power, which effectively offers compliance with performance based regulations taking into account the boiler systems used and the thermal performance of the fabric. In this context achieving low energy architecture is not a matter of ethical commitment but moves towards the practical issues of gaining building control approval without which no construction project is allowed to commence in the UK.

**Employers’ expectations**

Employers expect a graduate student who has acquired the skill to correlate various knowledge domains leading to the production of working drawing details using a number of software applications. Architectural technologists have to apply the multi-faceted knowledge of technical construction elements, design, and produce low energy buildings to comply with the UK government initiatives. In recent years the increasing awareness of clients on sustainability led the construction practice to develop major projects where reducing energy consumption while providing a comfortable environment is seen as an economic benefit (Swiss Re building, BED-Zed project, etc). Employers expect a graduate who capable to make decisions to deliver aesthetically pleasing energy conscious building.

**Pedagogical expectations in higher education**

There is no single theory application or a single definition of what is higher education. The common premise is that higher education is above the standard of GCE A-levels or National Vocational Qualification (NVQ) Level 3 (Higher Education Funding Council for England www.hefce.ac.uk). Universities translate this aim into their own expectations from their graduates.

Higher education expectations are connected to a constructivist approach. Constructivism theories aims towards a rounded graduate with more than just the simple acquisition of skills, but the ability to apply knowledge and a process of critical judgement (Spivey, 1997). These theories are translated into six main expectations

- demonstrate knowledge and understanding of essential facts, concepts, principles and theories relevant to their chosen discipline(s);
- the ability to critically analyse and solve problems;
- demonstrate a range of transferable skills including written and oral skills, information literacy and study skills, numeracy skills, IT skills, time management skills and team-working skills;
- the ability and desire to undertake lifelong learning;
- develop personally in ways which will enrich their lives and facilitate a full contribution to society in the future;
- acquire the skills to gain relevant employment.

Taking the triangle of expectations in consideration while designing courses or delivering modules is not a linear process, as these expectations change, but rather an iterative method in which tutors need to find a model upon which to benchmark their course design.
Course Design;

The educational policy of School of the Built Environment states that course design needs to maintain a balance between ‘independent but co-ordinated curriculum’. On operational grounds the application of this policy is unclear and needs an operational model for its implementation. Design and construction project modules can act as the nucleus in which different modules feed into. The need for curriculum integration evolved as a need to provide students with a platform to integrate knowledge gained during the academic year with the triangle of expectations.

The translation of the school policy into an operational model required challenging the norm of the modularization of modules delivered in isolation and therefore the need to identify an operational methodology towards an integrated curriculum. The construction graduate works within a professional environment to deliver a project in which various knowledge domains underpin decision making. A successful course design would not only rely on the constructivism approaches in higher education, where students develop understanding, logical and conceptual growth and the ability to apply critical judgements, but also to prepare the student to gradually relate to practical life and job expectations. This implies the need to emulate the decision making process by aligning the ‘Course Design’ to the intended levels of understanding and skills acquisition that needs to be developed by students(Biggs, 1999).

In the case of modular delivery, to achieve each individual modules outcome, there would have been three different assessments for each module. Figure 2: illustrates achieving the learning outcomes with separate assignments. In this context a certain module achieves its learning outcomes in a simple linear progression, with no relation to the delivery of other modules.

Students are assessed on their achieving the learning outcomes but there is no framework to test if they are able to synthesis their knowledge to a wider context where more variables are included in the decision making process. Current cognitive science theories are steering away from simple information processing models. Keil, (1998) argues that simple delivery models fail to capture the richness of natural cognitive systems. The primary implication of cognitive thinking on teaching and learning.

This work reports on efforts over the last three academic years. Design, visualise and reduce energy consumption are the main principals underlying the construction of low energy buildings. To achieve this goal, 3 modules were integrated, namely BE880: Professional practice project, BE881: Visualisation, BE879: Building envelope and services (Figure 1). The methodology aimed at students being able to design a sustainable house, visualize it then assess how construction technologies can be used to decrease energy consumption in buildings. Figure 1: explains the second year module grid.

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| Semester 1 | Management Skills BE209 10pts |
| Semester 2 | Design Principles & Procedures BE648 10pts |

| Building Technology Applications BE832 20pts | Building Envelope & Environmental Services BE879 20pts | CAD & 3D Visualisation BE881 20pts | Professional Practice Project AT BE880 20pts |

| Site Surveying BE834 10pts |

Figure 1: Second Year Module Grid
learning is the importance of structuring the experiences that involves the learner as an active participant in the process. Design projects can incorporate activities that require deeper levels of creating relational thinking. Simulation models offer a platform for hypothesis testing, while considering diverse assumptions and model input. Simulation tools support inquiry and discovery learning (Horne and Hamza, 2006), (Ramasundaram et al 2005), (de Jong et al, 1999; Frieder, et al 1990). Using visualization and environmental modelling techniques involves students exploring and synthesizing content of the three modules to test their own hypothesis on the effect of changes to building design on the environment and implications on the aesthetic value to achieve a low energy design.

The Structure of the Observed Learning Outcomes (SOLO) taxonomy proposed by Biggs and Collis (1982) identifies five stages for students to reach an expert like level of understanding. The SOLO Taxonomy offers a basic framework to assess the hypothesis that integrated modules offers an opportunity for students towards more complex levels of understanding, moving towards multi-structural, relational and extended abstract knowledge levels. Figure (3) presents an operational matrix where tutor input in each module (X axis) is mapped to expected levels of student understanding according to the SOLO taxonomy (Y-axis).

**Pre-structural:** In this stage tutors deliver the factual and theoretical knowledge. Expected Students’ understanding level allows them to list and define the basic principals for each module individually.

**Uni-structural:** Tutors move on towards connecting basic principals to case studies. Students start responding to individual learning outcomes in each module.

**Multi-structural:** Tutors teach students the software know-how. Students acquire a horizontal connection between modules, where they can manipulate a number of procedures and tools to apply principals gained in the previous stages.

**Relational:** Tutors support students to make a horizontal connection between the three modules. Students demonstrate an ability to critically judge the impact of their design decisions on aesthetics and energy consumption.

**Extended abstract:** Students deliver their final project, reflecting on how the procedure can be generalized to the construction of low-energy buildings.

In Figure 3: The operational model, The Y axis explains the expected level of student understanding at each phase of delivery, the X axis details the delivery.
<table>
<thead>
<tr>
<th>Expected level of understanding</th>
<th>BE 880: Professional Practice Project</th>
<th>BE 881: CAD and 3D Modelling</th>
<th>BE 879: Building Envelope and services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-structural: Listing definitions, looking at basic principals</td>
<td>Lectures and seminars on low-energy architecture, sustainable materials</td>
<td>Lectures and seminars on development of visualization techniques.</td>
<td>Lectures and seminars on expectations from building envelope, climate responsive definitions, listing building systems listing building</td>
</tr>
<tr>
<td>Uni-structural: connections of principals made to case studies</td>
<td>Analyzing site maps Preparing a list of required spaces to meet the design brief</td>
<td>Digital maps, case studies of visualized projects, Massing software</td>
<td>Case studies on Climatic integrative buildings</td>
</tr>
<tr>
<td>Multi-structural: Knowing how to manipulate and apply principals and theories Acquiring procedural knowledge</td>
<td>Analyze project site in relation to physical and social aspects Translating the list of spaces into a massing model</td>
<td>Using a number of visualization tools (sketchup, Revit, 3Dmax) to present own massing studies</td>
<td>Introduction to integrated environmental simulation software (IES V5) (variables include specific location, occupancy profiles, patterns of use) import initial house design from CAD software</td>
</tr>
<tr>
<td>Relational: Knowing when to use procedures Critically judging the impact of decisions on outcomes (energy consumption, function and aesthetics)</td>
<td>Produce a sustainable house design working drawing details using CAD</td>
<td>Apply optimum thermal performance to visualize changes in aesthetic appearance and construction technologies</td>
<td>Relates performance of buildings to occupancy, orientation, services used, and local climatic profile. Assess a number of alternative façade performances till optimum thermal performance is achieved.</td>
</tr>
</tbody>
</table>

The teaching team experience:

The members of the teaching team recognized the need for a project-based teaching methodology that moved away from the modularized delivery to a procedure that relates to decision making processes in practice.

This approach involves close co-ordination between staff teaching the three modules, especially on coordinating teaching delivery, assignment hand in dates, and devising marking procedures that would allow the student to be performance tested in each module without compromising the three modules. An initial student survey indicated potentials and pitfalls of this approach that needs to be further investigated and used to modify delivery of these modules in the future.

The teaching team believed that the way forward is to integrate principals of low energy architecture within existing courses.
rather than creating a stand alone specialized module on sustainable and low-energy architecture. Figure 4: Illustrates a sample of student work and assessment criteria

Students were more interested in applying the know how of using software and observing the impact of changes on their own designs. Their own project can create a single building model where various performance changes can be assessed virtually.

The ability to synthesize a number of project aspects (functionality, compliance with regulations, aesthetics and low-energy concepts) into a whole integrated final project of a sustainable house would pre-empt students to move to higher levels of understanding.

The availability of inter-operable software can create a virtual prototyping method to allow students to pre-test the thermal and visual performance of buildings aligned with structural requirements and aesthetic expectations to deliver a low-energy building.

The integration methodology requires more staff time dedicates to supporting students in the learning curve involved with manipulating different software applications. Software used between the modules must allow for inter-operability so students can import their 3D models into the environmental simulation software. The teaching team had to be trained to help students undergo this process.

Quality Assurance methods are strict programme requirements whenever a new teaching methodology is introduced. There have been concerns among the directors and senior managers of the school that integrated modules may need a major overhaul to the programme content, delivery and resources. This was not the case as careful mapping of the teaching and learning outcomes, only required changes to the delivery methods and the assignment briefs.

References


Freider Y. etal (1990) Learning scientific reasoning skills in microcomputer-based laboratory, Journal of research in science teaching, (Vol, 27), 173-191


Keil, F.(1998) Cognitive science and the origins of thought and knowledge, in Damon and Lerner (eds), Theoretical models of human development: Vol(1), Wiley


Engineering Education, Vol (28), no.2, pp.179-186

Ramasundaran, V. et al. (2005), development of an environmental virtual field laboratory, Computers and Education, Vol 45, pp. 21-34