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# Delivering Integrated Engineering and Architectural Design Education

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## Abstract
The relationship between the engineer and the architect remains the most significant association in the architectural design process and realisation of the built form.

In architectural education, the architectural design task is set to establish certain specific learning outcomes. However, the overall aspiration remains to establish holistic design capability. The writers have prepared and delivered an integrated educational programme that encourages the development of holistic thinking, across specifically the class subject areas of Building Technology and the Architectural Design Studio, within the BSc in Architectural Studies (Hons.) degree and within the multi-disciplinary projects undertaken by students studying for the Building Design Engineering (Hons) degree.

An integrated curriculum is fraught with issues of delivery and content. It must also be tested against contemporaneous issues which can impact negatively on this aspiration and can cause the dis-integration of holistic design capabilities. For instance, continuous advances in Computer Aided Design representation skills allow the student to present to a very high degree of sophistication which can sometimes mask their minimal understanding of basic structural or construction processes.
Other contemporaneous issues however such as sustainable design do present an opportunity to re-invigorate the relationship between the disciplines.

The writers maintain that the two professions, engineering and architecture, need to persist in identifying shared common ground in times of technological and environmental change. The paper proposes to present case studies as evidence of the writers' attempts to improve the mutual understanding and respect between the engineer and architect.

## Keywords
Integration, Holistic, Education

## 1. Introduction

*Learning is an interactive and dynamic process, in which imagination drives action in exploring and interacting with an environment."* (Schuller,1995).

The study of Architecture is a very wide programme encompassing many Artistic, Scientific and Engineering disciplines. At the University of Strathclyde, Department of Architecture, a typical undergraduate timetable for our main course the *BSc in Architectural Studies* dedicates mornings to lectures in subjects such as Architectural History and Theory, Media and Communication and Building Technology and Environment whilst reserving afternoons for the Architectural Design Studio.

The Architectural Design Studio is the part of the course that directly prepares students for practice by providing them with a series of challenging design projects. In order to successfully complete these projects, students have to call on a wide spectrum of "functioning" knowledge gained from lectures and combine this with their previous experience where relevant. Ideally, lecture material should be designed to inform studio projects whenever possible to align with "constructivist" approaches to learning which encourage a notion of continuous learning and the building on new and previous knowledge to create new experiences (Biggs, 2003).

The BTE (Building Technology and Environment) subject class covers all structural, constructional and material aspects of architecture. It also includes the study of building physics and environmental engineering design to allow students the opportunity to notionally design lighting, mechanical or natural ventilation systems and their building's energy supply strategy. As a subject field, BTE aims to provide students with the ability to understand various types of building structures, construction theories and environmental systems to ensure our future designers have the skills to create a high quality sustainable built environment for future generations.

During the last two years, our technology teaching programme has been re-written and enhanced to encourage deep and multi-functional modes of thinking like analysing and theorising. This is not just because educational research states that this generally produces high quality learning outcomes, but also because in professions like Architecture and Engineering the nature of the job involves solving a range of problems such as technical/engineering challenges, programme constraints and financial and contractual issues in order to successfully complete a building.

It is extremely difficult in a technical subject to adapt a pure lecture session to encourage students to move through the Kolb Learning cycle of new experience, reflection, integration and problem solving. However with recent innovations to the delivery of the course and its relationship with studio we are attempting to promote this deeper level of learning through concrete experience, reflective observation, and active experimentation (Biggs, 2003). This is being done through workshops, lab sessions, site visits and fully integrated studio projects.

Our traditional lecture teaching format is now being supplemented by additional seminars to allow the illustration of scientific theories within flexible seminars settings. Seminars can involve small student cohorts attending various material demonstration workshops or trips to laboratories, but we have also encouraged full scale building experience with materials such as cardboard to improve 3D visualisation and appreciation of scale. Regular support sessions for studio work and trips to local prestigious buildings have also been introduced to enhance the learning experience.

Seminars and workshops have made an enormous difference to our ability to understand the student learning experience in our courses by giving the lecturer the opportunity to iron out any learning difficulties and highlight any areas of the syllabus that need greater explanation and further development. From a social perspective, it has also allowed a more informal lecturer/student connection which is rewarding for both parties. Most importantly however, seminars develop a more integrated "functioning" knowledge within the students learning experience which is fundamental to our ambition of developing a holistic capability.

We have found that a significant factor - in addition to the development of an engaging learning environment - is to integrate the lecture and studio learning objectives and synthesise the learning experience in the formal and practical learning environment. In the first three years of our under-graduate programme, we are now beginning to achieve this integration and therefore student understanding of technical issues and the ability to problem solve for new design situations is becoming more evident in the work produced for the architectural design studio.

The ambition is that the student develops a cognitive capability to design holistically. Within an architectural education this is a complex aspiration. A considerable variety of conflicting ideas have to be introduced that are accessible to the student in all areas of the curriculum: theoretical, cultural and technical. All these issues have an implication in terms of design process and communication. The method to therefore achieve this ambition of holistic understanding is managed through a variety of co-ordinated teaching methods and scenarios within the learning environment described above. Realisation of this ambition is focussed within the design studio itself, a learning environment that by its very nature encourages a broad range of activities across all aspects of the curriculum. This ambition is realised within the *BSc in Architectural Studies* and *Building Design Engineering (BDE)* degree through the examination of our studio design programmes.

## 2. BSc in Architectural Studies: Curriculum Content

Within the Third Year architectural design studio programme, we expect to see evidence that the student is able to competently design a studio project holistically, with the additional requirement that students produce evidence of a specific integrated technological resolution. Students are directly assisted at this stage of their studies by direct tutorial input from both practicing consultant environmental and structural engineers. This is in addition to the weekly design tutorial support they get from practicing architects who contribute to the teaching of 50% of our curriculum. This means that from the outset of the course, our under-graduates have a great awareness of Architecture as a profession and the responsibilities of a qualified Architect in today's society.

The third year design programme requires students to investigate an urban housing scheme. The project requires the student to present strategic responses to a site and an engineering conceptual resolution as well as demanding the detailed examination of construction components, structural elements and environmental response. The results of this design project evidence all the 'threads' of technology that we identify as areas of dedicated architectural technological learning namely: structure (load bearing construction versus structural frames); construction (the process of assembly); detail and craft; materiality; environment and sustainability.

Each of these threads has been identified and investigated in earlier years of the under-graduate programme, sometimes explicitly, sometimes implicitly. The technology programme within these two initial years of studio utilises various dedicated teaching methods to do this such as learning by repetition and learning by example. This latter method uses architectural precedents as a learning tool and has been found to be beneficial in developing a sense of the reality of the technological aspect of the design process.

To fully understand how the holistic ambition is realised in the Third Year, the following describes how the threads of technology are embedded and delivered in the earlier years of our courses.

First year is a crucial year for students. The very first exercise set to first year students is 'the Box People'. Students are expected to construct a "full-size" box of pre-determined size to meet identified design criteria; the material choice is at their discretion. The year as a whole, numbering approximately

100 students, then erects the boxes in a series of live exercises. The structural and constructional issues relating to modular based construction are therefore investigated in real life full scale scenario.

All aspects of the implication of technology are implicated in this first exercise, including material choice, environmental response and attention to detail and craft, and therefore the threads of learning have been established from the outset.

**Figure 1: The Box People**

Building technology knowledge is known to benefit from experiential learning. Therefore after 'The Box People' students go on to consider further design tasks with an expectation that these will also be realised in full-scale constructions. The Architectural design studio exercise 'To Furnish' requires that the students both collectively and individually examine what it means "to support." The task requires the students to design from first principles a structure to support a human figure in a given pose. Individual design solutions are peer evaluated and then constructed full-scale in a specified material - nominally cardboard. These structures are then tested, often successfully but on occasion to destruction.

Following this exercise students are then asked to take their design proposal and put both human figure and supporting structure into a 'Room with a View'. This exercise is realised again full-scale in a "live exercise" using canes and string thus effectively providing a comparison between frame construction ideas to the preceding load-bearing boxes. All have by implication continued the educational agenda of the process of assembly, craft and materiality.

**Figure 2: To Furnish/Room with a View**

Second semester design projects repeat this comparison. The first project, 'To Dwell' focuses on load bearing (façade study), and the second "To Settle" focuses on framed construction (a whole building study). At this stage the student is additionally being asked to represent these ideas in a two dimensional

drawing format as it is a necessity for an architect or engineer to be able to effectively graphically communicate both at a technical as well as a design intention level.

Throughout the design studio programme, the BTE class mirrors the technological aspiration of the design studio with seminar and lecture content. Specifically seminars continue the idea of learning by experience by constructing structures with both the human form in the "Body – Building" seminar as well as with chosen selective materials – in the "Cardboard and Spaghetti Towers" workshops.

**Figure 3: Body-Building**

**Figure 4: Cardboard Towers**

The Second Year continues on from the First Year experiences in technological investigation. However, from the generalisations of technological investigations established in First Year, the Second Year aims to be more specific in its approach to the teaching of technological issues and emphasises an analytical approach to learning. The Year 3 programme in turn places a greater emphasis on synthesis of this intrinsic knowledge.

The two semesters focus on two notional ideas: 'Structure and Detail' and 'Material Choice and Detail'. Technology teaching throughout recognises the value in seeking specific answers to the student's specific problem. The issue of students copying generic details from magazines has been identified as a major problem in delivering technology teaching in studio. By making BTE assignments directly apply to each student's individual design project, we have encouraged a level of personal commitment to the subject, thus ensuring greater adherence to the assignment requirements and greater understanding of the design problem.

In first semester all the design studio exercises are concentrated on a limited material type - nominally timber. The Architectural project briefs are therefore at a scale that could in reality be built in such a material. The 2nd year BTE classes provide specific teaching content to support this selected material and its specific assignment requests a variety of representational formats from the students including drawings, models and sketches. Essentially, it focuses on how they design and detail a fairly simple medium scale public building with a large primary space.

In the second semester, it is expected that the student will select the construction method and structural material and present it as a resolved architectural design proposal mid-way through the semester. This proposal is then tested independently against a series of engineering issues such as structure, process of assembly, building regulation, internal environment and sustainability. These exercises are designed to engage the student, and also to develop his/her adaptability in design capability.

Furthermore, they are expected to understand the environmental impact of their design choices and methods for lighting, heating and ventilating their building. All of this design work has to be evidenced graphically in A1 or A2 size plans, sections, elevations, axonometrics and 3D computer images. The production of detailed drawings at 1:10 and 1:20 scale is also required to provide detailed evidence of the student's technological and engineering knowledge of their design.

Throughout the first two years of under-graduate study the Architectural student is therefore immersed in a whole series of exercises and activities into the nature of what it means to build. After Third Year the expectation is that the student becomes considerably more sophisticated in their ability to manage a wide variety of engineering and technological design issues. The student is then expected to consolidate their prior learning within the architectural studio and also enthusiastically engage in the necessary team-work required in architectural practice. Team working has a major role within the curriculum generally. A whole series of identified exercises introduces the student to a wide variety of team working events, ranging from small groups (pairings) to larger scale (units/year group) across a variety of tasks such as designing, researching, analysing and performing. The multi-disciplinarity of the subject area however is brought together explicitly in the *Building Design Engineering (BDE)* course which is run in parallel to the BSc under-graduate and post-graduate course. The innovations described above in our teaching of technology inform both of these under-graduate programmes.

## 3. Building Design Engineering

Twenty years ago a multi—disciplinary course entitled *Building Design Engineering (BDE)* was set up within our Department to try and encourage multi-disciplinary working for Architects and address some of the perceived lack of holistic design skills displayed by some structural and environmental engineering under-graduates and their lack of contact with their particular profession. The educational aims of the BDE programme are to essentially produce graduate architects and engineers with a high degree of design ability whilst at the same time fostering inter-disciplinary respect and communication through common roots, a shared curriculum and challenging design studio projects. Students can graduate in each of the three professional disciplines that the course educates: Structural Engineering, Environmental Engineering and Architecture. The course is accredited by the RIBA, ICE, IStructE and CIBSE.

The engineering aspects of Architectural design are covered in the BTE course which both BSc Architecture students and BDE students study. The BTE class is assisted by good relationships with other Departments in the Faculty of Engineering. This gives us the opportunity to pursue multi-disciplinary working between under-graduates from different Departments and utilise engineering expertise, notably from within the Mechanical Engineering and the Civil Engineering Departments.

BDE provides a common educational programme for the first two years of study, requiring all students to undertake traditional engineering subjects as well as participate in a design studio environment. It is a very challenging curriculum for these early years but then allows the student to choose their professional discipline at the end of second year. From 3$^{rd}$ year onwards the students are trained in their own unique discipline but come together in an architectural studio for 25% of the academic year to develop a multi-disciplinary design project. The briefs written for these projects tend to be for large, challenging buildings such as sports centres, libraries etc to allow all the members of the team to excel in their own unique discipline.

Historically the BDE studio was kept separate from our BSc studio, so only BDE architects could work with BDE engineers. However, a couple of years ago, it was decided, for a number of reasons, to change the organization of the BDE studios in third year to allow the BDE students to integrate into the BSc studio.

The architecture stream of BDE worked on the urban housing programme in 1st semester and the BDE engineers joined the studio in 2nd semester to design a Music Academy in the Merchant City Area of Glasgow City Centre. All engineering students worked within their project design team to develop their project to a detailed level sufficient to demonstrate the relationship between their overall architectural and structural and environmental engineering concepts and their detailed design decisions.

Engineering students studying on the BDE course are required to produce structural and environmental reports on their building between 8,000 and 10,000 words long which have to include conceptual engineering strategies and schematics, calculations of the sizes and connections of major elements and technical details that illustrate a holistic engineering design knowledge. The engineers must also demonstrate that they have contributed meaningfully to the project as the project structural or mechanical engineer from initial concept stage through to project completion.

Bringing in BDE structural and environmental engineering students into a thriving BSc studio with 70-90 architectural students was successful in that the engineers and architects worked very well together despite the numbers of engineers being relatively small - four to five in each discipline. They were split between the four Architectural Units (22 students) and carried out research into their particular Unit's building typology which they then presented to the entire unit. Mid way through the semester they paired up with an individual architect and worked on their unique structural/environmental strategies for individual schemes.

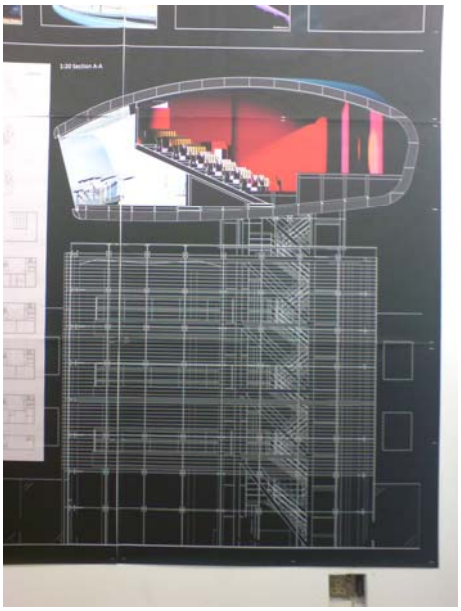

**Figure 5: BDE Year 3 Music Academy Design Proposal**

This cohort of students then went on to work together in the 4th year of the BSc. The agenda for this year was to develop formal architectural design sophistication. The final project of the year set an agenda to examine the notion of architectural detail by using a relatively small building programme set in an international context – in this case a Research Library in Eichstaett, Germany. This project, even though

dissimilar in tone to the studio project previously set for BDE students, yielded a fruitful opportunity for the various disciplines to share the challenges and joys of architectural design.

**Figure 6: Research Library in Eichstaett**

## 4. Conclusion

At the University of Strathclyde, the Department of Architecture is embedded within a highly successful Engineering Faculty. One might expect that the influence of this relationship would naturally enhance the attitude to the teaching of technological matters within an architectural education, and certainly the adjacent departments and faculty encourage this. However, an unnatural resistance can exist within this central facet of the architectural agenda, the roots of this perhaps lying in a perception that an architect illustrates architectural space and form, but is not the constructor of it. This has possibly been exacerbated by the fact that within education in recent years there has been a dependency more and more on the computer as a means of representation. Its powerful graphical capabilities allow students to produce highly sophisticated 3-dimensional imagery devoid of any actual reality of the construction. Furthermore, within the architectural profession itself, the architects' role, has been considerably undermined through changes in contract roles.

Fundamentally, the nature of architecture is that it is ultimately realised in physical form and all the implications that go into realising this physical form ie structure, construction, material and detail, all have implications for spatial arrangement, spatial quality and ultimately the totality of the architecture itself. It is therefore the aspiration of the Department of Architecture that it encompasses all the influences that affect the architectural design process; a significant aspect of this being the technological imperative.

*"You have to be a plastic artist and a poet, as well as a thoroughly knowledgeable technician"*
*Le Corbusier*

## 5. References


Bennett, M., and Carre´, C. (1993). *Learning to Teach,* Routledge, London.

Biggs, J. (2003). *Teaching for Quality Learning at University: Second Edition,* SRHE & Open University Press, Buckingham.

Boekaerts, M. (1997). *Self Regulated Learning: A New Concept Embraced by Researchers, Policy Makers, Educators, Teachers and Students.* Learning and Instruction, 7, 2, pp.161 -186.

Boud, D., Cohen, R., and Walker, D. (1993). *Using Experience for Learning,* SRHE & Open University Press, Buckingham.

Cowan, J. (1998). *On Becoming an Innovative University Teacher: Reflection in Action,* SRHE & Open University Press, Buckingham.

Fry, H. Ketteridge, S., and Marshall, S. (1999). *A Handbook for Teaching and Learning in Higher Education: Enhancing Academic Practice* Kogan Page Limited, London.

Kember, D. (1997). *A Reconceptualisation of the Research into University Academics' Conceptions of Teaching,* Learning and Instruction, 7, 2, pp.161-186.

Martin, E. (1999). *Changing Academic Work: Developing the Learning University,* Open University Press, Buckingham, Philadelphia.

Miller, A.H., Imrie, B.W., and Cox, K. (1998). *Student Assessment in Higher Education: A Handbook for Assessing Performance,* Kogan Page Limited, London.

OECD. (2002). *Responding to Student Expectations,* OECD Publications.

Prosser, M., and Trigwell, K. (1999). *Understanding Learning and Teaching: The Experience in Higher Education,* SRHE & Open University Press, Buckingham.

Race, P. (1999). *2000 Tips for Lecturers,* Kogan Page Limited, London.

Wisker, G., and Brown, S. (1996). *Enabling Student Learning: Systems and Strategies,* Kogan Page, London & SEDA, Birmingham.

Learning and Teaching Support Network (online) Available URL: www.ltsn.ac.uk/genericcentre