PAPER FOR AIARG JAN 2016

INTRODUCTION

"I hear and I forget. I see and I remember. I do and I understand" - Chinese proverb
"For the things we have to learn before we can do, we learn by doing" - Aristotle

Architecture and engineering courses traditionally include theoretical training in materials, construction and structures, often "supported" by making small models - we might call it the "spaghetti bridge building syndrome". These are highly misleading as models of structural behaviour - they cannot be interpreted with linear scaling relationships to real, full size structures, so students may not appreciate real loads, stresses, deflections, and dynamic behaviour. Similarly, a feeling for the intrinsic properties of materials, how to work, or join them together, is greatly enhanced working with full-size structures. The physical intuitions that can be engendered can cover not only physical behaviour, but also aesthetic sensibilities, including scale and form.

The development, over several decades, of a series of full-scale construction projects at a number of universities, including UCC, has aimed to remedy such shortcomings. We ran these projects primarily as hands-on practising architects, rather than academics, and those providing supplementary tutorial and technical support were also generally from a practical background. In the case of engineering students, there were added benefits for them, seeing practical inter-professional collaboration in action, with us bringing more overtly architectural perspectives to the table.
We have also found that students engaging in practical problem-solving as teams of manageable size gained valuable project-management skills

The practical learning benefits may be summarised under the following headings:-

- **working to limited budget**

- **working to limited time**

- **developing the ability to plan** and programme the whole project - design, procurement, prototyping, testing details, fabrication and erection

- **where real users are involved**, the ability to discuss design intent, and respond to user needs

- **testing, and critical evaluation** of finished structures (even where the constructions have shortcomings - understanding a failure can be more informative than a structure which succeeds for unknown reasons)

- **developing an intuitive "feel"** for behaviour, material properties, & how to make connections

- **appreciation of what is possible with low-cost materials and self-build**, in situations where lack of resources and housing or shelter are pressing needs

Projects typically run for three to five weeks full time, or an equivalent if part time: a total of the order of 75-125 hours, a good proportion of which should be tutorial contact, with students working ideally in groups of four to five.

Structures are typically around 5 -10m spans, usually light weight, and low cost.

These attributes are clearly interrelated, but we can examine them one by one, starting with structural characteristics and types:-

LIGHT WEIGHT

Speed of fabrication and safety are obvious benefits which flow from light weight: the structures can be made in a safely supervised environment and transported to open sites for erection, and the testing of their behaviour can be experimented with more safely by students, so that they can develop a real intuitive "feel" for how structures behave, in comparison to theoretical expectations.

For example:

inflatables: permit very quick fabrication, low costs, instant results, but students need to understand the special, and limited, scope of relevance to building needs - they need to be introduced with illustrations of real large-scale built projects

photos: UCL Bartlett, University of East London
Glastonbury Festival shelter

tensile membrane structures: again, can be very low cost, quick to fabricate, and in heavier coated fabrics, can have a life expectancy of five to ten years or more

photos: projects at Cambridge University,
UCC 4th year engineering students
CCAE shelters

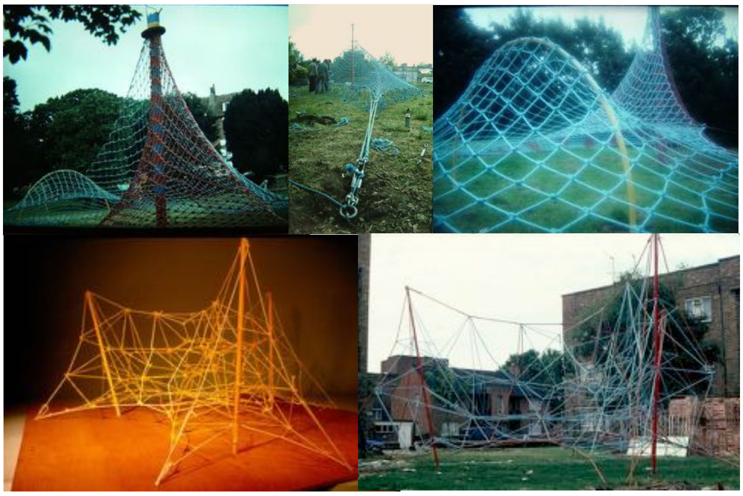
timber lattice grids: moderately quick fabrication and erection, they can display remarkably high structural efficiency; this example was used as a children's climbing frame, and could carry the load of a dozen adults with minimal deflection

photos: E London, hospital for children with disabilities

nets: for example, as climbing structures - easy to construct, can be quick to make, depending on net fabrication (knotting, splicing or clamping); they are likely to require supporting compression elements

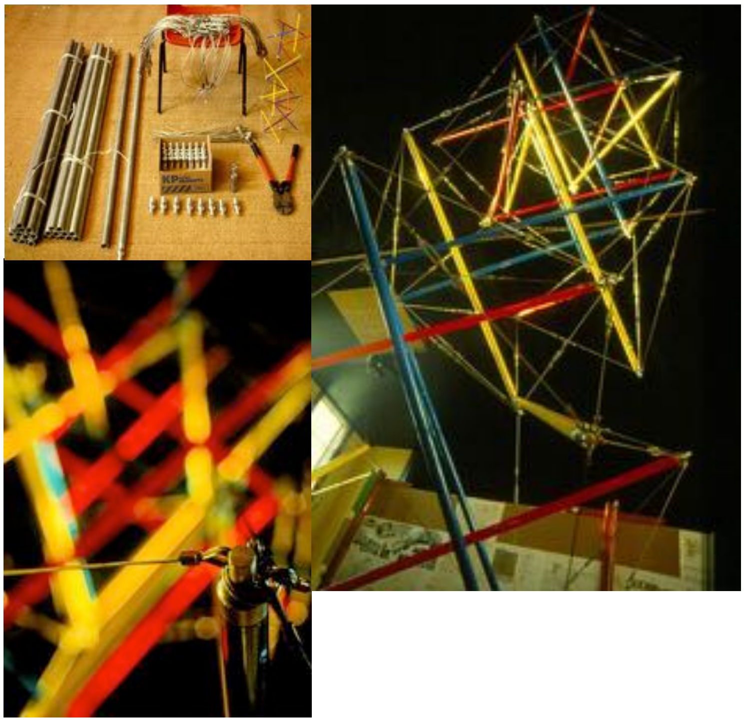
photos: climbing nets, Brighton, E London

3-D climbing net L B Haringey



tensegrity structures represent an especially interesting challenge: grasping their special characteristics, three-dimensional geometric rules, the relationship of tension to compression elements, an appreciation of their unique physical properties -

liveliness, and sensitivity to uneven tuning. Given the limitations of their intrinsic properties, these may need to be college-funded where no client or "useful" function can be found.
photos: E London



However, there was one instance where we found an ostensibly "useful" application for a tensegrity structure, as a pergola for scented climbing shrubs, for severely handicapped or sensorily limited children.

photos: Hospital for children with disabilities, Walthamstow

The range of structural types can be quite diverse, occasionally even heavyweight

photos: Hospital for children with disabilities, Walthamstow
London Borough of Haringey Play Service

WORKING TO A LIMITED BUDGET

If there are no real clients paying, the college can set a budget, usually quite modest, say, €100 - €500 per structure, i.e. large enough to make full-size structures, but demanding economy and careful thought about materials - ideally recyclable or recycled, and possibly structures that can serve a useful purpose within the college, or a secondary purpose elsewhere.
Where the college pays for materials, quite modest budgets can result in structures of useful size

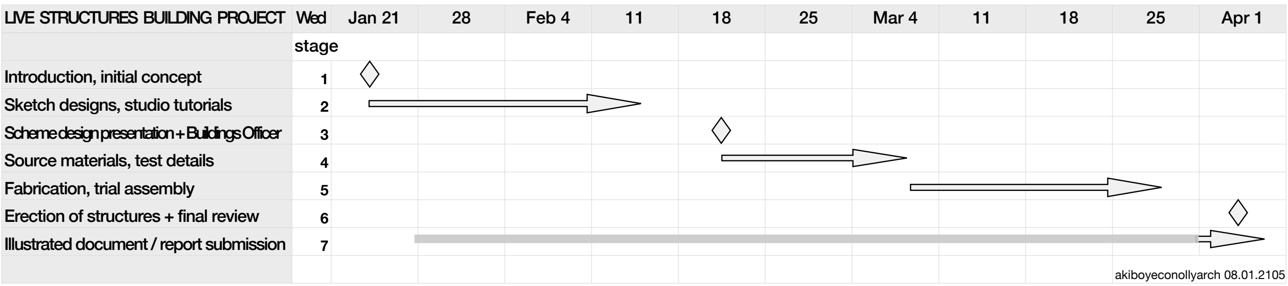
Final year UCC engineering students, working under Prof Ger Kiely and Dr Denis Kelliher produced some mid-sized structures, and a number of smaller structures were developed at CCAE - shelters, market stalls, under year co-ordinators Orla McKeever and Sarah Mulrooney.

photos: bike rack covers &
shelters/market stalls at UCC and CCAE

WORKING TO LIMITED TIME -

developing the ability to plan and programme the whole project - design, procurement, prototyping, testing details, fabrication and erection.

Depending on other commitments, these projects have run for anything from a few days, to four or five weeks, even ten to twelve weeks where students have a heavy burden of other work. They should be clearly programmed, with defined milestones for tutors to check progress at every stage.



Above: UCC 4th year engineers programme

It has been suggested this diagram implies a linear design process; this is far from the case. The reality of time constraints focuses students' minds, and acts as an antidote to the all-too-frequent syndrome of leaving things to the last minute. The realities for students of having to present a design proposal with one eye on where they are going to buy the materials, ensure that they have the right properties, how much they cost, how long they take to deliver, and how they are going to be worked - all develop a mature and lively awareness of the realities of the whole process of design, with all its feedback loops, through to construction. Close tutorial guidance is essential.

The optimum group size is four to five students. This encourages awareness of how best to develop collaborative working; in a group of this size, all members can recognise the importance of planning how to share the work, defining tasks - learning project management, in other words - and are aware of the details of what other members are doing. We have found that larger groups run the risk of carrying "passengers" who may not pull their weight.

A few projects have worked with small groups of 2 or 3; this requires very focussed and intensive input from the individuals, but tends to limit the scale of construction.

photos: bike rack covers & shelters at UCC
inter-team collaboration

far right, small structure at CCAE

WHERE REAL USERS ARE INVOLVED,

to discuss design intent, and respond to user needs.

Designing play structures for a number of hospitals for handicapped children, or homes for displaced or orphaned children provided not only really useful budgets (some of the order of €600 - €1500) for relatively durable constructions but a number of other opportunities to confront real issues which the students would encounter in future practice.

Students were coached in the skills of explaining their design intent to lay clients, using appropriate means of presentation, drawings and models, listening to any comments or feedback, and responding to it.

photos: sandpit cover, Norwich

climbing frame, Epsom,

musical wind sculpture for disabled children, E London

Even if there are no actual clients, getting proposals approved by college authorities, or at the very least, the course tutors, can be an interesting challenge, similar to obtaining approvals from regulatory authorities. Health and Safety officers in particular can oblige students to focus very carefully on exactly how structures are to be erected, how much they weigh, and how to avoid or minimise risks in the process - just as they will have to do in real practice.

photos: UCC 4th year engineering students presenting designs to Buildings and Estates Safety Officer

TESTING, AND CRITICAL EVALUATION

of finished structures (even where the constructions have shortcomings - understanding a failure can be more informative than a structure which succeeds for unknown reasons).

It may be unkind to include the deliberate testing to destruction of the structures, and we have not usually demanded this - it can be demoralising, and wasteful not only of potentially useful constructions, but can undermine the sense of achievement - students enjoy standing back and admiring their handiwork. Even without testing to ultimate load, it is easy to intuit the margins of over- or under-design. If a structure does fail, this can offer the richest learning experience; analysing and discussing why, and what could be done differently. As with many aspects of such projects, skilled, close and sympathetic tutorial guidance is essential.

photos: climbing frame, Epsom

photo: UCC 4th year engineering students "load test"

DEVELOPING AN INTUITIVE FEEL FOR BEHAVIOUR, material properties, and how to make connections

All too often, analysis of the performance of a construction remains a theoretical exercise in design and engineering courses. No intuitive understanding flows from this process. To build a full-size construction, handle the challenges of joining materials together, see how joints behave, and to simply feel how the whole structure behaves, is an unforgettable experience. The materials chosen will have a significant influence on the process and tools required, and should be matched to the resources available to students. Learning the limits to what can be done with each material, the scope of what can be done with the right tools and processes, and opportunities to test full size pieces, all contribute to the value of the exercise - learning how to develop appropriate designs suited to the materials.

photos:

UCC workshop 4th yr engineering students & materials, self-built shelter in local timber & forestry thinnings, in-situ glulam with Hooke Park students

E London: polythene tent; simple catenary edge detailing
industrial sewing machine stitching pvc coated fabric
6m curved ply web beam fabrication

APPRECIATE WHAT IS POSSIBLE WITH LOW COST MATERIALS AND SELF-BUILD, in situations where lack of resources and housing or shelter are pressing needs.

In a world where many non-renewable resources are dwindling, and may be unaffordable to large sectors of humanity, an awareness of the environmental impact of everything we do in construction, in a global context, has special importance.

Simply recognising that the process of building need not be the exclusive preserve of an established industry (and its associated professionals) with vested interests in monopolising the delivery of buildings, also has a special value.

photos: experimental shelter, west Cork with Hooke Park students - locally sourced timbers, in-situ lamination
Glastonbury Festival shelter

TUTORIAL SUPPORT

The projects benefit from close support by tutors with relevant experience and interests - for some it may require a willingness to take risks. It is imperative that students feel secure in exploring speculative propositions, or pushing the boundaries of established techniques, knowing that they will be guided in a constructive way towards successful outcomes by their tutors. A broad familiarity with a range of materials and an understanding of the techniques by which they can be worked is vital. The tutors to run such projects, and equally any supporting technicians, should be selected to cover these; their knowledge and confidence is essential to foster confidence in students whilst exploring and pushing the bounds of possibility.

ASSESSMENT

We have also explored the benefits of transparency in assessment, and encouraged self-assessment by students of their work. The assessment criteria, and their relative weighting, are set out in the project brief. We have also offered to adjust the weighting of these criteria if students wish to design with an emphasis on special aims, for example, using recycled or scrap materials. (This rarely happens, but this is perhaps just a reflection of the novelty of such a proposition, handing over greater autonomy and responsibility to students for their education.) Our feedback at the end of the project includes our commentary on the group's achievement against these criteria; we make it clear that ambitious and imaginative solutions, rather than necessarily predictably safe designs, will be amply rewarded, especially if accompanied by a self-critical analysis in the students' record of the project. This is especially valuable in structures which may not perform fully as intended. Whilst the main product is the finished structure, we remind students that their report assessing their view of how well they have done, and what they might do differently to improve the outcome, is an important part of the learning process.

We also ask students to reflect on the group interaction, to discuss their awareness of the dynamics of collaboration, individual and collective learning.

An incidental benefit for students who may be at a stage where they will shortly be seeking employment, is the record they have made of the project, which is of value at job interviews.

CONCLUSION

In summary, the projects mimic real-world practice in a safe and supervised setting where "failure" is redefined, is not a disaster, and can be appreciated as an enhanced learning experience - students see what went wrong, and will make sure that it doesn't in a real-life project.

In universities with related departments - architecture, engineering, material science, surveying, arts, planning, social sciences - further benefits are possible by running joint projects, so that students, who often spend their entire courses in segregated departments, learn how to collaborate with other professions, just as they will have to do in their professional working lives.

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