DEVELOPING CORE SKILLS IN CIVIL ENGINEERING STUDENTS USING AN APPLICATIONS APPROACH

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INTRODUCTION

This text will discuss the use of three synoptically linked first year modules to teach core skills in the civil engineering curriculum using a contextualised problem based learning approach. The modules were developed following recognition that traditional first year engineering courses, consisting primarily of modules in mathematics, mechanics and construction materials were perceived as being rather dull. Anecdotal evidence suggested that this was contributing to a lack of motivation in the Year 1 cohort. An essential aspect of the modules is the use of experiential learning by the linking of experimental work to design calculations. Design exercises used this year include an investigation of the collapse of the World Trade Centre towers, the layout of a road network for a major housing and retail development and the realignment of a canal under one of Scotland's busiest motorways. This was supported by site visits to emphasise how theory is brought into practice and oral presentations to encourage research and group working. Student feedback suggests that the modules have been successful in achieving their main aims and that students in the early years of the civil engineering degree course now have a clearer idea of the application of knowledge taught in traditional lecture courses.

BACKGROUND

Up until Session 00/01 the Civil Engineering students studied the following programme during Year 1:

Term 1	111UA	Foundation Maths 1 (service taught)
	141MB	Chemistry for Engineering B (service taught)
	211CI	Computing and Information Technology
	211MA	Mechanics A
Term 2	111UB	Foundation Maths 2 (service taught)
	211CS	Communication Skills
	211ES	Environmental Science
	211MB	Mechanics B
Term 3	111UC	Foundation Maths 3 (service taught)
	211DD	Civil Engineering Development and Drawing
	211MC	Mechanics C
	211MT	Materials A

Two problems were noted with this arrangement:

- Some students entering the course highly motivated slowly lost motivation as there was little real world application in the delivery/content of the fundamental subjects (maths, chemistry, mechanics and materials).
- Academics argued that the standard of C&IT awareness amongst recent cohorts made basic instruction in this area largely redundant. The departure of an academic related member of staff who taught this module was viewed as an opportunity to overhaul its content and delivery.

These factors combined led to the decision to replace 211CI, 211CS & 211DD with three "applications modules", named Civil Engineering Applications 1, 2 and 3 (CEA1, CEA2 & CEA3). The aim of these synoptically linked modules is to provide students with the following transferable skills which are utilised throughout the course:

• C&IT skills (Inc Web Research & e-mail) • Written communication skills • Oral communication & presentation skills • Group working skills	Summative & Formative Outcome
• Conceptual design skills • Problem solving skills	Formative outcome only

The summative aims are largely the same as those of the modules which were replaced. The formative aims were constructed to reflect the learning aims of the civil engineering programme and the QAA benchmark statements[a] for “intellectual abilities”. The main change in the modules is the delivery method and how the learning outcomes are measured.

The module which CEA1 replaced focused on ensuring students had sufficient C&IT and presentation skills. In the past, to deliver the material as efficiently as possible assessments were often devoid of a civil engineering context. For example, word processing skills were assessed by setting the students the task of writing their CV. Whilst the student group did obtain the necessary C&IT skills, the approach had the following problems:

1. Decontextualising the assessments did not improve student motivation, nor did it give Term 1-Year 1 students the grounding in the subject it was thought they required.
2. By giving non civil engineering related assessments an opportunity is missed to transfer course related skills/knowledge (e.g. laboratory report writing skills) – i.e. the learning potential of the session was not maximised.

These observations were supported by the following piece of student feedback:

> *“The coursework was pointless.... If it had been integrated with other subjects e.g. having to hand in a mechanics report in a word format, the time spent would have been relevant....”*

The new modules have also been designed within the context of the whole course. Beyond Year 1, each year of the UG Civil Engineering degree has a strong design theme where the student group is expected to work on open ended and realistic problems. Additionally, attaining problem solving skills is one of the key learning outcomes of the civil engineering course.

This text will focus on the delivery of CEA1 and CEA2, but will also consider how student feedback has been used to inform the approach.

UNDERPINNING PEDAGOGY

Central to the module design was the concept that students who had good perceptions of teaching and learning would develop better study habits and consequently demonstrate a deeper level of learning(1). It was expected that a favourable learning experience in the CEA modules would impact on the other modules throughout the rest of the course.

Another key concept used in the development of the module was *outcome centred design*(2). This approach, where applied to module design, utilises a three-stage design/learning model:

1. The module is expressed in terms of outcomes (formative & summative).
2. The module delivery should be learner centred.
3. There is congruence between learning, assessment, teaching and outcomes.

Using this approach, the learning is student centred and is not lead by either assessments or teaching style. Whilst applying this approach to a new module was straightforward, it was recognised that more effort would be required where a module (and its associated resources) was well established.

Research has also shown(3) that first year students perform best in the school type learning environment which they have become used to when compared to the traditional university lecture-tutorial-exam approach to learning. Within that context, a decision was made to provide a mixed-mode learning environment. In an effort to maximise student learning(4&5), it was decided that this would rely heavily on civil orientated problem based learning (PBL). PBL has been used in education for some time, however it was not until the 1960’s that is was formalised as a learning tool in higher education(2). Its use has become more accepted since the mid-1990’s, when it was adopted in several UK medical schools(9). The method relies on the educator providing the student group with a problem scenario, and the students are then expected to work on developing a solution. The learners are expected to then explore the problem using their existing knowledge and understanding. The educator’s role is as a (non-didactic) facilitator(9). Although problem based learning is associated with medical schools, it is also used outside that field – particularly in engineering (4&5).

The decision was made to contextualise the teaching material as literature, and experience, suggested that this would offer the best way of motivating the student group(2,8-12). By adopting PBL within a group working context, it was viewed as having the following advantages(13):

1. Development of problem solving skills.
2. Motivation is enhanced when students are permitted to tackle problems imaginatively.
3. Development of peer learning.

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[a] http://www.qaa.ac.uk/crntwork/benchmark/engineering.pdf

Despite these considerations, PBL was however known to allow weak students to be carried by others. For this reason, it was proposed that for some activities students would also be assessed on an individual basis.

Another common criticism of PBL, and other "innovative" teaching methods, is that students find the change of learning environments problematic – especially when the course is predominately delivered using a single method (normally via traditional lectures/tutorials). To avoid this, the module was not introduced to the students as being different. Furthermore, evidence was also found in the literature which suggested that students would be able to switch between delivery modes with relative ease[14].

Both experience within the module team and research[5] suggested that some students may struggle in medium or large class sizes[b]. Whilst this is often a feature of service taught modules (in this Year 1 case Maths & Chemistry) it was decided to see the class as a single group as little as possible. When the class was brought together, group working was used as the norm to provide a more intimate learning environment.

One of the main aims of the three CEA modules was to introduce the Year 1 students to the concept of "design" as this is a theme which runs through the entire course. This was viewed as essential as research indicated that one of the key issues in student learning was being able to "connect" to the institutional culture[15]. Within this context, the modules sought to provide an introduction to conceptual design.

COURSE DELIVERY

A decision was made at an early stage to use continual assessment together with PBL to ensure the students reached the learning outcomes specified. This was because it was thought that a large amount of civil engineering contextualised assessments would engage the students and give them some grounding in the field of civil engineering. It was anticipated that the learning environment would conceptually mimic a real world workplace setting; strict project deadlines, group minute taking etc.

As part of the first CEA1 class, the module was introduced to the class. It was demonstrated to the students how assessments mapped onto the learning outcomes. Time was also taken to demonstrated how the students were expected to learn. This was undertaken by informally describing Laurillard's[11] "Conversational Framework". Key emphasis was placed on the students forming an informal conversational relationship with the teaching staff and their peers to promote learning/understanding. This was seen as being crucial; as it was felt fresher students may feel a little daunted by the unfamiliar institutional structure. It was also emphasised to the students that they would probably differ in terms of which method of study would work best for them, and they should not allow themselves to be coerced down any single path.

The use of a formal C&IT learning environment was also considered. However, as the emphasis of the module was on group working (a key skill evaluated by both the QAA and professional accreditation bodies), it was concluded that a C&IT learning environment may not have provided the optimum solution for full-time Year 1 undergraduates. Notwithstanding that, directed C&IT learning formed the basis of much of the project work – the emphasis of this was largely off-campus information resources.

It was recognised that Term 1-Year 1 students would only have the knowledge they brought with them and that a proportion of the class would be returning to education (~10%). Each of the assessment activities were formulated within that context. The assessments may be described as outlined below.

Laboratory Sessions

The laboratory sessions were designed so that as much of the student group as possible would be able to take an active role. The assessment was undertaken via an individual laboratory report – the main summative outcome being the assessment of C&IT skills. However, the laboratory sessions were also focused on attaining student confidence with the following:

1. experimental methods – ability to follow a procedure and accuracy issues;
2. laboratory report writing skills;
3. Civil Engineering terminology;
4. group working; and
5. safety issues.

These aims were reached by setting a series of three linked laboratory experiments:

1. aggregate particle size analysis;
2. specifying a (prescribed) concrete mix based on a desired strength, workability, durability and the aggregate size analysis data; and

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[b] Lucas et al[5], Suggest than a large class is >90 and a small one is <20. The CEA1 class size was 68.

3. testing the resultant concrete, and assessing its ability to meet the desired strength and durability.

These tests were relatively inexpensive to undertake and provided a range of experiences for the student group (e.g. group working, referring to BS/EN codes, error estimation etc.).

Site Visit

The site visit assessment set the students the task of writing a report based on a class trip to a local Civil Engineering construction site. Again, the assessment was undertaken via an individual report – the main summative outcome being the assessment of C&IT skills. However, the activity was also focused on attaining student confidence with the following:

- report writing skills;
- Civil Engineering terminology; and
- safety issues.

The sites visits were selected in such a manner that they reflected the work being undertaken on campus. The main aim for Term 1 was for the students to be given an overview of how concrete is placed on site. The visits were all limited to three hours (including travel), and were arranged via research/consultancy/educational links with industry. The visits varied in size from a small pier renovation (£1m) up to the Falkirk Wheel / Millennium Link Project (£78m)[c].

Research Project

For the Research Projects the students were given the name of a new or recently constructed landmark civil engineering structure. In groups, they were set the task of finding out as much as possible about the structure and presenting their findings to the rest of the class. The summative outcome here was the assessment of C&IT, presentation and oral communication skills together with group working ability. However, the activity was also focused on attaining student confidence with the following:

- Civil Engineering terminology;
- familiarity with civil engineering internet resources; and
- familiarity with the campus library.

For this activity the students were split into pre-selected groups of 3-4 students.

Estimation

This exercise set the students the task of quantifying a quantity which was difficult to quantify – e.g. estimate how much paint would be required to paint the Forth Bridge. The aim of this was to show how problem solving using a (simple) mathematical model can reduce workload. The students were expected to work in groups to solve the problem.

The main focus of these enabling exercises was providing the students with the experience, confidence and skills to complete the design exercises – these were designed to allow the integration of knowledge and understanding at a basic level. Again, reference was made to the learning aims of the civil engineering programme and the QAA benchmark statements to design these exercises. Specifically, the design exercises were designed to provide the following challenges to the student group:

1. presentation of technical information;
2. placing a project within a commercial context;
3. applying technical knowledge to an unfamiliar context; and
4. managing work within a group to meet a firm deadline.

The design exercises may be summarised as follows:

Collapse of the WTC	The students were asked, in groups, to evaluate a element of the WTC design. Each group reported back to the class. This information was then used to consider how the towers collapsed the way they did.
Redevelopment of the Ravenscraig Site.	The exercise basically required the students to design a a "new-town". The students were expected to pay particular attention to transport infrastructure.
Access to the Balfron Campus	This exercise required the students to design pedestrian, cyclist and vehicular access to the Balfron Campus – a PFI funded High School/Leisure Complex and Community Centre

[c] Pictures from some of the visits may be viewed at: http://www.civ.hw.ac.uk/research/sysgeo/staff_sa.htm

M8/Union Canal realignment	As part of the Millennium Link project the Union Canal had to pass over or under the M8. This project asked the students to provide a design.

The student group responded in different ways to each of the design exercises. Most interesting was that relating to the Balfron Campus. With that exercise, it was noted that each of the groups spent time discussing access to their school. This was viewed being a valuable “ice-breaker” at a time n the course when the students have only developed tentative relationships with others in their cohort.

The project the students responded best to was the M8/Union Canal realignment. When the M8 was designed the Union Canal had fallen into disuse. The designers decided that the canal should be culverted as the M8 passed over it (Figure 1). The culvert was not designed to allow any craft to pass through it. This was because the local topography was such that the would be insufficient height.

For the canal to be reopened the students had to recognise from plans that there was insufficient separation between the canal and road surface levels. Once this was realised a number of generic solutions could be devised by the students:

1. Raising the level of the road
2. Lowering the level of the canal using locks and pumps
3. Design a boat lift
4. Take advantage of the sloping topography and realign the canal so that it may pass under the M8 a few hundred metres away.

As engineering solutions, each of the above are viable. However, only the fourth could be justified economically without including secondary tourism benefits.

The students were expected to provide a conceptual designs along with a report which detailed their inspirations and other designs they considered. The groups were also expected to give an overview of how their design could be implemented with minimal disruption to motorway traffic.

The nature of the designs varied considerably. The better groups were able to fully appreciate the problem and produce a workable and economically sustainable solution (Figure 2). Other groups produced designs that were admirable, but may not have been economically viable (Figure 3). The poorest groups generated designs which failed to really tackle the problem. Figure 4 illustrates a design which would perhaps be better suited to a rural back-road than a busy motorway.

The assessment exercises were supported by a number of stand alone lectures which sought to introduce key concepts to the student group (e.g. sustainability) together with basic C&IT instruction sessions. Other than that, the majority of the knowledge was gained by the students first recognising that there was a need, and then deriving a route to attain the required outcome – an approach justified in teaching and learning literature[(16)]. The method for this varied from staff mentoring, to searching the internet or campus library.

The main focus of the term was providing the students with the experience, confidence and skills to complete the design exercises – these were designed to allow the integration of knowledge and understanding at a basic level. Again, reference was made to the learning aims of the civil engineering programme and the QAA[d] benchmark statements to design these exercises specifically. They were designed to provide the following challenges to the student group:

- presentation of technical information;
- placing a project within a commercial context;
- applying technical knowledge to an unfamiliar context; and
- managing work within a group to meet a firm deadline.

STUDENT FEEDBACK

Within the module delivery session informal student feedback was good. Submitted assessments also indicated that the student group was responding well to the module. The only real problem related to C&IT skills - around 25% of the class were having problems using Excel. Based on this feedback, it was realised that an extra sessions would be required – this took the form of a 3-hour C&IT ‘clinic’ session where the students were

[d] For session 2001/02 the engineering faculty was assessed by the QAA and was award the top ranking of “commendable”. Key to achieving this was the role group working and design education within the undergraduate course provision.

encouraged to bring their partly completed work with them – based on informal feedback, this session worked well.

To supplement this informal feedback, a further four more formal avenues were open for the students to provide feedback. These are outlined below.

14.10.01 Class Meeting
At this session the class was asked, as a whole, how they were finding the module. This was an opportunity for the mode of delivery to be fine-tuned (or to change drastically) depending on student feedback. Feedback was good. The only negative point raised was the large size of laboratory groups.

19.11.01 Academic Councillor
As one of the aims of CEA1 was to improve student motivation across the course, a session was timetabled to hear the opinions of students who were perceived to have low motivation. This was done by writing to a number of students (25%) based on their attendance and assessment performance in CEA1 & Mechanics A. This exercise was undertaken in consultation with and assistance from the campus's academic councillor.

This session appeared to be of value to those who took part. Five demonstrated significant enough improvement in performance to subsequently pass the module.

23.11.01 Stop Start Continue
Although the formal feedback gathered by the department is very useful. It was thought that "Stop Start Continue"[e] would help inform the delivery of CEA2. The results of the feedback can be summarised as follows:

- Overall, the comments were both constructive (100%) and positive.
- The main theme in the feedback is that there is uncertainty regarding assessments. This perhaps reflects the open-ended nature of many of the problems that were set.
- The students requested more site visits and practical sessions.
- The students requested more group projects as part of the module assessment.

The feedback related to assessment guidance was expected. Inside and outside timetabled sessions students often asked for "model solutions". Although this was not collaborated, it was suggested that perhaps the students were often provided with model solutions at school. Literature also suggested that a significant proportion of the students may find open-ended problems a little disconcerting[16] and would search for *the* correct solution.

30.11.01 Formal Feedback
Formal student feedback collated at departmental level takes the form of a questionnaire augmented by a request for written comments. Generally, the CEA1 module was well received and held in high regard compared to other modules that term. Comparisons with the feedback from the previous session (2000/01) indicated that the applications approach was a marked improvement. Typical comments for 2001/02 were:

"*Group work is what we want*"
"*Continuous feedback helps let us know how we are doing*"
"*Group work on specific interesting topics in the public eye was good*"

Overall, the student feedback (both formal and informal) was both constructive and positive; it was rewarding to see that so many students had benefited from the module. Despite this more students than expected failed to reach the pass threshold – nine in total. Of these, however, a number had already decided not to continue with the course[f]. The same approach to course delivery was employed in Term 2 (CEA2). By that point in the academic calendar, the students had become familiar to the PBL approach, and were seen to be responding well. However, the increasing workloads elsewhere in the term meant that the continual assessment deadlines (7 in total) inevitably caused conflicts with assessment activities – a factor which was reflected in student feedback.

Informal feedback obtained during the CEA3 sessions in Term 3 indicated that the students are responding well to the assessment types used, and are being encultured into both the mode of learning offered and, more generally, into civil engineering. Within that context, the aim of providing the students with a grounding in the

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[e] For an overview of "Stop Start Continue" see: http://www.pegasuscom.com/levpoints/stopstart.html

[f] Heriot-Watt University has an above average student retention rate. Key to this is identifying students which perhaps have not chosen a course which best suits their future career/life goals and allowing them to transfer within the campus.

civil engineering design philosophy used in the course can be considered a success. Being able to develop the student group in this manner allows them to use design as a 'tool', and enables them to communicate their approach more effectively within the learning environment – this, in itself, is known to promote higher levels of learning and cognition[17].

RESOURCES

The modules were designed to require a maximum 50 hours of contact time each (100 "student effort hours" per module). This was shared between four members of academic staff and supported by the departments "Honorary Professor". In terms of staff resources, the most problematic issue was the scheduling of site visits. Site mangers welcomed the student visits, however safety and site constrains made access for the class as a whole difficult. Typically, only 15-30 students could visit a site at any one time – this consequently consumed a large amount of staff time and was difficult to schedule within the staff/student timetable.

THE NEXT ITERATION

Overall, the approach used was viewed to be a success. However, some changes have been proposed which will be reflected in session 2002/03. These were as follows.

1. Stress the nature of PBL, and that there may be several very different but equally valid solutions. It was observed that some students with poorer social skills struggled in group work, an observation which was supported by literature[14]. As both teaching and learning literature and experience suggests, this situation is best countered with more reassurance and facilitation[17]. Typically, those with poorer social skills also had lower than average entrance qualifications, and this may also have exacerbated the problem. It was also noted that the students returning to education within the class tended to work together rather than fully integrate within the class.
2. Attain resources to significantly reduce laboratory group sizes.
3. Allow more time in the timetabled sessions for basic C&IT instruction.
4. Include the whole class in the session with the academic councillor.

It is hoped that with these changes in place, the Year 1 cohort for 2002/03 will be able to benefit considerably.

CONCLUSION

The learning environment provided for the students proved to be a success in terms of both meeting learning outcomes and maintaining student motivation whilst proving to be an efficient use of resources. In particular, the student cohort responded well to group work exercises, although it was noted that some students with poorer social skills needed extra encouragement.

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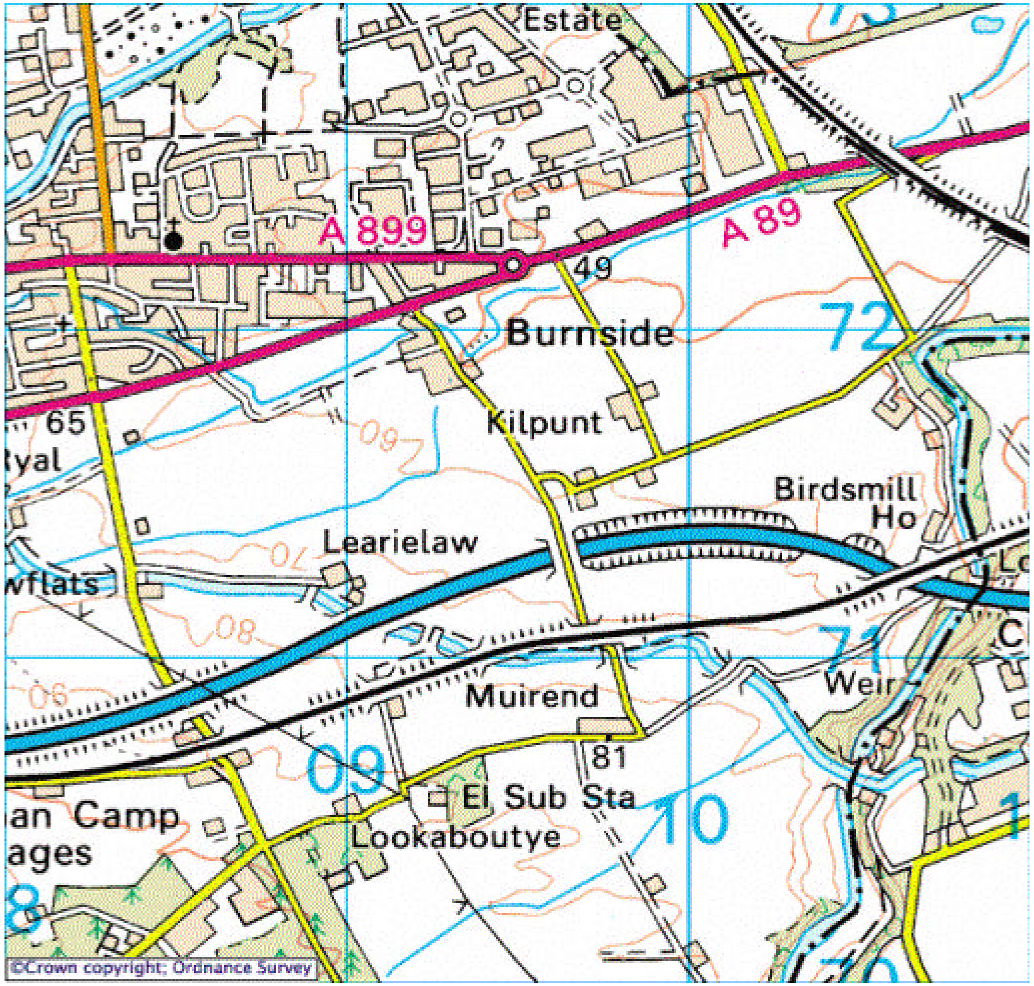

Figure 1: Location Plan

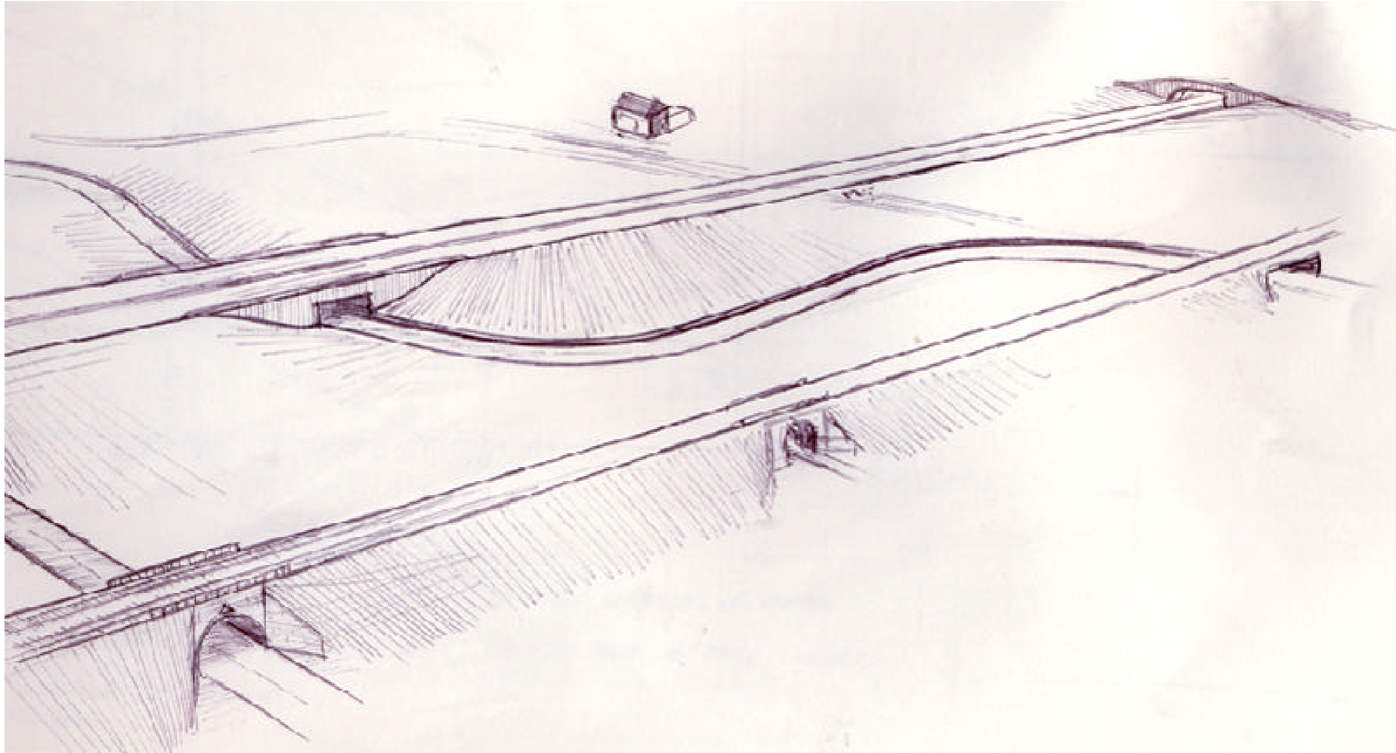

Figure 2: An Example of a good schematic design.

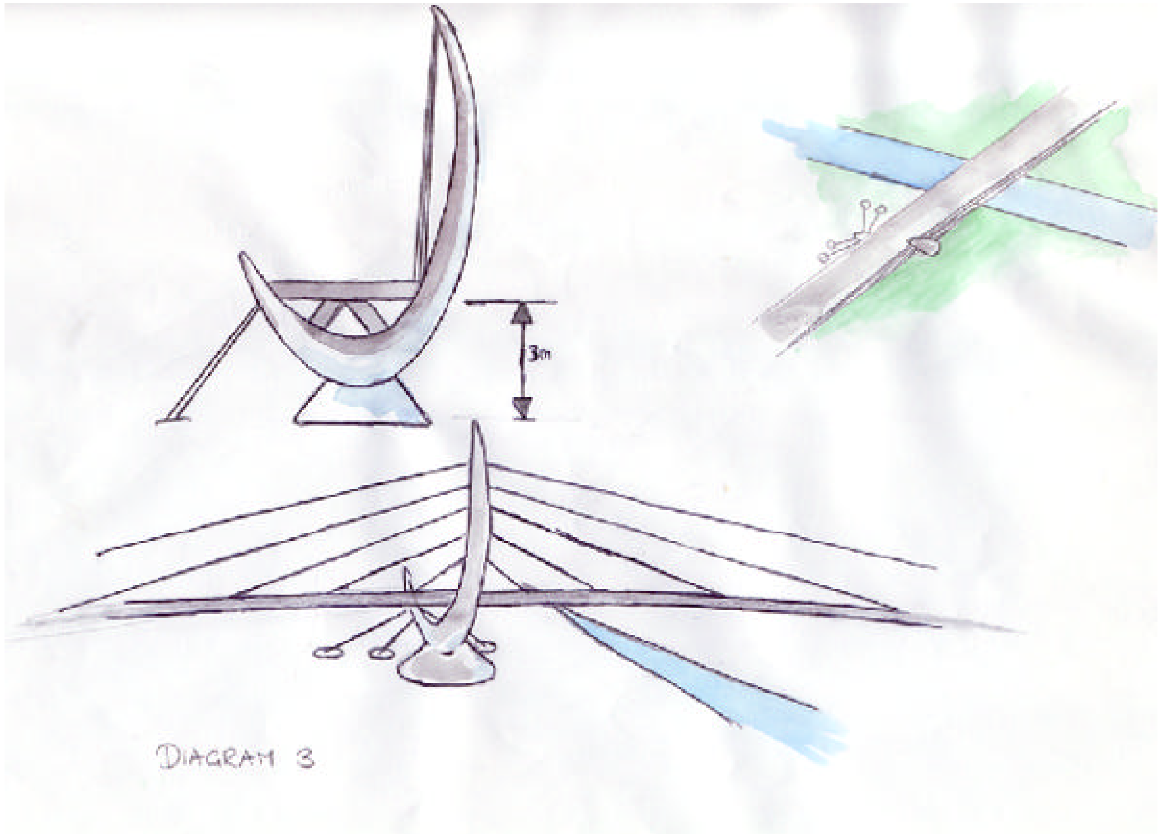

Figure 3: An Example of a good schematic design which may not have been economically viable.

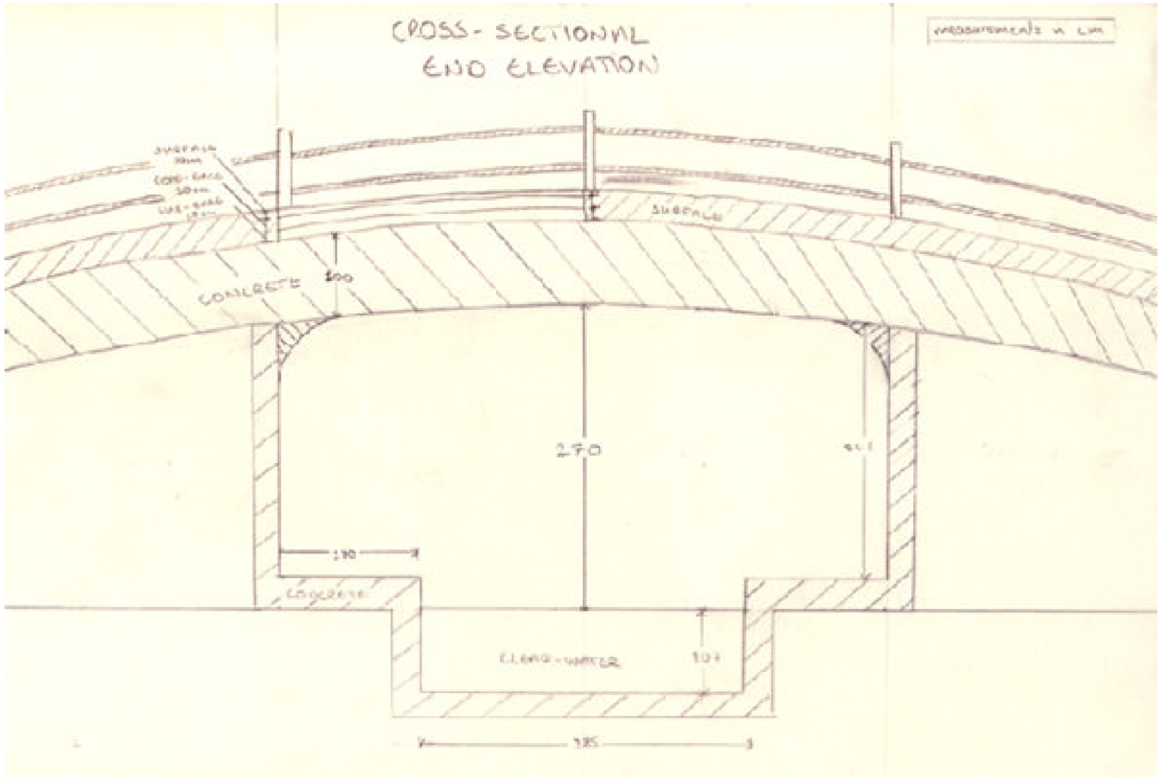

Figure 4: An Example of a poor schematic design.