Teaching Building Services to Architecture and Building Students

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ABSTRACT: Building environmental services can often be categorised as ‘one of the least desirable courses’ in the curriculum of architecture and building. Nevertheless, it is also one of the most important and confronting subjects in the procurement of real building projects. The principal message to designers is that of spatial requirements while to the builders it may become one of capital cost, installation specifications and maintenance of equipment. Getting these concepts across in a creative, yet project oriented, manner can be challenging to the students and to the lecturer. This paper presents the developments of ten years of teaching the subject, as well as the methods of delivery which have proven to be successful.

Conference themes: Education of future architects
Keywords: Building Services, Integration, Sustainability

INTRODUCTION
Teaching building services to architects and builders can present quite a challenge for a lecturer. The desire to engage with the services and mechanical aspects of a building is often of little interest to the student who has intentions of landmark designs. Building services are considered by architecture and building students as the engineer's duty and responsibility. This lack of interest in the subject can become quite an onerous and undesired task for the lecturer to overcome. So why is it that we require this subject in the curriculum of architecture and building?

Certainly, the answer to the above question is quite obvious to the experienced architect and builder. At the experienced level, such a person has confronted the realities of making buildings work and providing the services to do so. In this process, the experienced architect or builder has recognised the ramifications of neglected planning for services and the consequences of ignorance of such in the procurement of buildings. This foresight, or lack of it, is very real in the profession. However, it does not serve a convincing argument to the student who has not encountered such experiences. How can a course in the subject matter convey its importance at the level of a student?

The answers lie in establishing an interest and appreciation for the subject. This requirement may be above and beyond other courses such as the design studio, history, and construction, where the course material appears directly related and automatically accepted to be part of the curriculum. Convincing the architect and/or building student that they are to become the future leaders in the processes leading towards sustainable architecture is the first step. If a student or practitioner is not aware of the functioning of a particular service, and whether it is required or adequately sized, there is no appreciation for it. If we do not appreciate the functioning of a service, we remain ignorant to how it can be improved or better integrated into our buildings.

Since services comprise the major energy component of our buildings, the need to reduce or replace this energy requirement with renewable energy sources is fundamental to sustainability. Therefore, students and practitioners who do not have some understanding of the servicing equipment (efficiency, load requirements, schedules of operation, location, etc.) in their building, are not even remotely prepared to encounter a rethinking of service design and its integration. Such architects and/or builders have in ‘blind faith’ left several serious components of sustainability for ‘others’ to resolve, and will never engage (nor would it be possible from them to engage) in a progressive and innovative project.

It is important to obtain student awareness of their future role and responsibilities, as an architect or a builder, related to building services. This can be accomplished partially by realising their impact and decision making role in the procurement process of building services. Furthermore, by studying and experiencing the services installation (on real projects), they are confronted with such responsibilities through various consultants and reflect upon their own as an architect or builder.

In conjunction with their awareness of a planning process, getting the student to recognise that there is a significant spatial requirement among building services is of fundamental importance. Once this spatial requirement is acknowledged and furthermore ‘experienced’, the student begins to accept his role in the subject matter. It is believed that such can only be accomplished through physical experience, hence calling for project-based learning. When the student has gained an appreciation for the spatial requirement of building services it is important to move on to
understanding why such requirements are needed. After the ‘realisation’ for building services has taken place, the next step is to learn the roles and functioning of each service and its location in the building.

This paper aims at outlining a step-by-step project-based assignment directed towards building services. The discussion will centre on a major project which is undertaken by groups of students in the architecture and building course. Generally, groups of 4-6 students are comprised from both the architecture and building courses. Each group is assigned a commercial building which contains the requirement of transportation (lifts), fire, HVAC (mechanical air conditioning) and electrical, communication, and water services. Such a reporting task can become quite an overwhelming assignment for the students. This paper proposes a method on how to breakdown and conquer this huge task among each of the student groups.

1. COURSE CONTENT AND PROJECT OBJECTIVES

The course text, *Building services: a guide to integrated design* by Dr. P. ParLOUR (2000), provides a clear mission to the students. His main statement establishes that building services are in fact very real entities, take up floor area, volume, and, above all, require careful planning within the design concept of the building (ParLOUR 2000). This requirement is furthermore supported through the introductory lecture, where examples of services and their location throughout several buildings are presented. A guiding phrase of the unit for the student is to ‘explore the uninhabited, behind-the-scenes, portions of the building’.

The specific aims of the course as stated in the unit outline are supportive of this theme:

a) Emphasise buildings as a total expression of integrated systems & services;
b) Explain the operation and function of technical service systems applicable to buildings of medium to high complexity;
c) Emphasise the planning, location of equipment, accessibility and the occupied area for the particular service within the building;
d) Building systems integration is viewed as a study in system design analysis in terms of optimal organisation, energy efficiency and sustainability. Such is presented in relation to a particular service and its application in the context of various building types and occupancies.

Due to the increasing numbers of student enrolments in the subject, as well as catering to the curriculum of two courses in the School of Architecture and Building, project-based group work has become essential (Tucker, Rollo 2005). The students perform individual assignments throughout tutorial and lecture sessions, comprising 20% of the course marks. One of the more successful individual assignments introduced to the course is the ‘How Does it Work?’ presentation, in which students explain the functioning of a particular service or system to the rest of the class.

The major building assignment involves groups of 4-6 students, investigating the services of a real building. These buildings are generally hand-picked by the lecturer after having been cleared by the building management staff. Students are asked to develop a list of questions prior to their visit with the building manager. They are also encouraged to sketch the major circumstances, which can also be accompanied by digital photos. Of prime importance is obtaining a layout (floor plan) of the building. However, since quite often the drawings of a project are not released and are not allowed to leave the premises, building managers are asked to provide a place on the site for students to study, review, and redraw the required building information.

In the early years of the course development, 6-8 students studied a particular building, gathering information as a group, but processing and reporting results individually. This resulted in a substantial amount of repetitive material as well as a limited quantity and quality of information. In a sense 6-8 projects were graded which all appeared to be similar in content with very little value-adding to the subject matter. It wasn’t until the project buildings were assigned into groups that the level of information collected was on average 3-4 times that of individual assignments. The reporting methods, graphics, and organisation were also improved significantly for each building. It can therefore be concluded that this is an assignment benefited by group work.

The objective for the major project is for the students to ‘explore the uninhabited portions of a building’ and to do so experientially. This project allows the student to see and learn through experiencing, researching, and conversing with others readdressing the services of a real building. Students, within their group, are often allocated to investigate a specific service (HVAC, fire, electrical, transportation, etc.). As a group, they will all be working on producing a presentation (in Power Point) of the services within a particular building. The dissemination of knowledge among these various services reaches all members of the group through the information processing methods provided in the forthcoming project outline explanation… Furthermore, the standard, from non-group projects, is raised because each student focuses on a particular segment (only) of the total project.

2. AN OUTLINE FOR THE MAJOR PROJECT

Achieving successful outcomes on the major project took several years of teaching refinement.

The management of assessment stages and their requirements needed to take place so that levels of performance expectations were understood by the lecturer as well as the students. Having the lecturer organise the building selection for the project is the single most contributing factor to the major project success. Once the building managers or owners accept the project and understand what is involved, the chance of student success in obtaining information is greater.
Although the organisation is an onerous task for the lecturer, it is advantageous, eliminating potential excuses and failures on behalf of the students.

Experience has also shown that building managers are often interested in the student outcomes and are favourable to repeating the project in the following year.

2.1. Major Project Areas of Investigation
The ‘areas of investigation’ outline the expected building services to be studied. Often each group will assign a member or two to each of the following services:
- Mechanical HVAC systems
- System Zoning
- Transport Services
- Electrical Services
- Communication and Building Control
- Water Services and Usage
- Fire Safety and Systems

‘Doubling up’, where two members take on 2-3 of the major services together, often occurs. The organisational methods are anyway left for the group to decide:

An additional guide to these areas of investigation suggests the information to be collected under each service. These are not provided in this paper, yet a ‘method of investigation’ probably provides the most important checklist for a comprehensive analysis of each service. The seven categories comprising the ‘method of investigation’ with a brief description are listed below:
- **System type**: is identified and best explained through a hierarchical or overview diagram.
- **System components**: are presented through an overview diagram and their operation is explained individually as part of a whole system
- **System Area / Volume**: is identified through the 3-D model and calculated separately for each service.
- **Systems location and zoning**: is identified through the application of a 3-D building carcass and floor plan areas, where individual services are identified and zones regarding the equipment location or operation are highlighted.
- **System installation**: is in part explained through collaborative information and the 3-D building model
- **System maintenance**: is provided through collaborative investigation with various building consultants.
- **System integration within the building**: is explored experientially and studied through individual evaluation and assessment.

The assessment considers how well each of the above ‘methods of investigation’ is addressed in the project output. Under each of the categories, a brief explanation in regards to the particular system is expected. These are further supported by diagrams, hierarchical charts, drawings and photos. The five W’s (who, what, where, why and when) are to be answered in the dialogue of the presentation.

2.2. Major Project Assessment Intervals
In order to assure progress as well as group project organisation, experience indicated that presentation reviews needed to take place throughout the semester. Although this appears to be cumbersome for the assessors, it is actually a time saving device. It provides for a student-lecturer familiarity with each project building and group, while also assuring a better quality product by the students. Generally after the second meeting, students obtain a pretty good understanding of the project. At each of the initial presentation sessions, the lecturer (assessor) has the opportunity to provide critique and suggestions on how the group performance and the method of investigation can be improved before the final product submission.

<table>
<thead>
<tr>
<th>Table 1: First Presentation Assessment Criteria</th>
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<tbody>
<tr>
<td>25%</td>
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<tr>
<td>Building Approval Established</td>
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<tr>
<td>Established Contacts - List</td>
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<td>Access to information established</td>
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<tr>
<td>Group members organised</td>
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<tr>
<td>Development of interview / site questions</td>
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<tr>
<td>Template Design – Presentation &amp; font</td>
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<td>Template Outline - TOC</td>
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<td>Template Navigation</td>
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<td>Level of information collected</td>
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<td>Group meetings – project time schedule</td>
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<td>Group effort on presentation delivery</td>
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Once the students have been assigned a project building, they are expected to make immediate contact (generally with the building manager) in order to introduce themselves, establish approval and coordinate an initial meeting. While this is taking place, they are to consider the areas and methods of investigation in regards to developing a template in PowerPoint which will accommodate the required material. This process provides a useful outline (the individual templates) into which the collected material and information will be placed. Students are provided references to previous year projects for assistance to their own project template organisation. This initial assessment presentation takes place within the first three weeks of the semester. The three presentation sessions are discussed below through the following assessment tables. Table 1 provides the criteria for the first presentation.

At about six to seven weeks into the semester, the second assessment presentation is held. Table 2 contains a similar format to that of Table 1, yet different information and progress on actual data collection and requirements within the project template are expected.

<table>
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<tr>
<th>Table 2: Second Presentation Assessment Criteria</th>
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<tr>
<td>Criteria</td>
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<tr>
<td>Location of Building</td>
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<td>Size of Building: m², m³</td>
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<tr>
<td>Development of 3D Model</td>
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<tr>
<td>Location of Services in 3D model</td>
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<tr>
<td>Area of each service: HVAC, Elec. etc.</td>
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<tr>
<td>Service Overview Diagram - components</td>
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<tr>
<td>Hierarchy of system overview</td>
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<tr>
<td>Information integrated into presentation</td>
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<tr>
<td>Appropriate presentation &amp; neatness</td>
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<tr>
<td>Group presentation efforts</td>
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For some unexplainable reason, the largest struggle on most projects was to obtain a 2-D and 3-D modelling of the building examined. It took several years for the lecturer and tutors to realise that the major difficulty rested within the type of collected information on the services. Examining working drawings is often very complex, overwhelming, and a far cry from the simplification of the building floor plan, structure, and volume information required for this project. It wasn’t until the overall project objectives were revisited, that the message was re-established for students studying building services. Architects and builders are not engineers and relate three dimensionally regarding the placement of these services. A 3-D, carcass modelling of the building, without all its extraneous complexities, is all that is needed to represent the building shell, as a separate entity from the building services.

In the past, several groups have relied on sophisticated 3-D programs like Microstation and 3-D MAX to construct their models. Until recently, if the students among a group had limited CAD skills the results obtained would be mediocre at best. Nevertheless, through the use of a new program called ‘Sketch-Up’, a very simple software package, the students can easily provide the essentials of a 3-D model for this assignment. Due to the encouraged use of this simplified modelling tool, it has now been determined that the three dimensional model is a prerequisite to the final project submission, with the model development being part of the second review requirements.

By the time the groups have experienced the first two review sessions, the requirements (in most cases) are clear as to what is necessary for the third review session. For this third assessment, it is important to obtain a near completed PowerPoint presentation. Generally, this presentation takes place in the 11th or 12th week (the final two weeks) of the semester.

The final review is unassisted by students and evaluated by the teachers from a CD-ROM submission. For this review, the lecturer has time to examine the entire subject matter and assess the project in terms of its overall content and efforts. The final review sheet (not shown here) contains all the services of investigation as well as a peak load energy calculation category.

3. PROJECT OUTCOMES AND CONTENT

3.1. Student Results

When commencing the study of a particular service, it is expected that the student will revert to the seven ‘methods of investigation’. The first two methods - system type and system components - strongly suggest that a diagrammatic overview be established.

An example of such an overview is provided in the hierarchical electrical diagram of Figure 1. This particular diagram is not uncommon in concept to what would be required of the remaining services. Such a diagram convinces the lecturer that the fundamental concept of a particular service and its organisation within the building is understood. Furthermore, it provides the student with an outline of the components to be investigated in detail. In the case of the electrical service example, it would be expected to have the following explained in detail:
Once the overall organisation of a service is considered by the student, a natural segue into applying the remaining 'methods of investigation' occurs. The next step, constructed concurrently within the outlining of various services, is the development of the 3-D building model. As stated earlier, it is important for the student to bring this mental spatial image of the building services into a virtual 3-D model. Figure 2 provides a more finalised example of a model where all the major building services and their location have been identified.
There are of course intermediate stages between the hierarchical diagram and that of the completed 3-D model. Generally, it is advised that the presentation provide the overall ‘summary’ of the total building area and volume as compared to a breakdown of service areas, as a starting point in the Power Point presentation; however, such may not yet be developed at the initial stages of the project. It is useful to present the total gross area of the building alongside the total service area as an overview leading into the particular building project. Figure 2 with its service area breakdown therefore lends itself well for the introduction of the overall building presentation.

There is, of course, a substantial amount of information provided in the intermediate stages between the above presented outputs of Figures 1 and 2. For instance, a detailed investigation into the various components of the particular services has not been shown here. There are additional individual assignments which are supportive of this detailed information. One of these successful assignments is the ‘How Does It Work’ presentation (see Figure 3).

### 2. Student Comments and Reflection

It is somewhat controversial and not appropriate to compare this course with others taken in the same semester and in the curriculum of the architecture and building courses in general. However, through the student course evaluation process and the additional comments made on such, there is some indication that students did learn and benefit from the project and teaching method. Some of these are as follows:

- “a very important subject in the course...”;
- “one of the most crucial subjects in the entire course...enlightening the blood and guts of the building and proposing environmental alternatives, which is fantastic”;  
- “very elaborate subject, very succinct and easy to understand and to appreciate new environmental techniques... a capacity to think outside the conventional design and service principles”;  
- “very passionately taught by the lecturers and tutors”.

The above comments as well as the overall student evaluation for this course are quite satisfactory and suggest that the objectives of the course have been achieved. Although encouraging to a lecturer, there is always room for improvement and constructive criticism. Some of these are:

- “need to be more organised and clear as to project requirements”;
- “it was boring through parts...which dulled my motivation”;

For the lecture topic of each week there are between 8-10 service products or concepts which are assigned to several students. Each student will have the opportunity to investigate, review and present in a 3-5 minute presentation during the lecture period. These singular topic presentations are provided electronically and are put into the web site of the course for student access.

The ‘How Does it Work’ session has become one of the highlights of the course. Students are genuinely interested in researching the various topics and enjoy experiencing their peers present a segment of the lecture. Quite often there is a questioning, discussion and intervention period among the topics. This is all very productive, provides an enormous resource of information, and develops an appreciation for building services.

### 3.2. Student Comments and Reflection

Indirect Evaporative Cooling

What is Indirect Evaporative Cooling?

Indirect Evaporative Cooling processes by which moisture is added to air in order to reduce the temperature and increase the relative humidity. The lower the relative humidity, the greater the cooling effect that is possible when moisture is added.

The principle is relatively simple. Air moving past moist water will cause the water to evaporate. The heat necessary to cause evaporation is drawn out of the passing airstream and hence the air is cooled. The human body uses this principle to control body temperature by varying the amount of moisture on the skin surface (perspiration). The evaporation of the moisture cools the skin and helps to lower the body temperature.

Indirect Evaporative Cooling is not a new idea and has been used for thousands of years. However, new technology has provided more effective, economical and environmentally friendly cooling solutions which have made possible two, other types of evaporative cooling: Indirect Evaporative Cooling and Indirect/Direct Evaporative Cooling.

**What is Dry and Wet Bulb Temperature?**

- **Dry Bulb Temperature** is the air temperature which is measured by a dry bulb thermometer
- **Wet Bulb Temperature** is the temperature at which water is at equilibrium with the air temperature.

**How does it work?**

Indirect Evaporative Cooling uses a fan to draw moist outdoor air through a wet cloth where the air is cooled by the evaporation of water within the pads. The cooled air is then directed or distributed into the building via a supply fan. The temp pads are wet by a pump which pumps water up to the top of the pad from where it trickles down. The moisture content of the supplied air is reduced due to the cooled (condensed) air stream and is particularly effective in dry climates.

**What is the difference between the Wet and Dry Bulb temperatures?**

The greater the difference between the Wet and Dry bulb temperatures, the greater the achievable temperature reduction.

**Why Bulbs?**

- Bulbs are the accepted method of temperature measurement.
- Bulbs are stable and show greater changes in temperature than other methods which are not conducive for Evaporative Cooling.

**Benefits of Evaporative Cooling**

- Economical
  - Reduces cooling requirements
  - Lower initial costs (20-50%)
  - Lowers the cost of mechanical equipment cooling
  - Reduces the energy required for cooling processes
  - Increases air conditioning in hot/temperate regions
- Environmentally friendly
  - Does not use chlorofluorocarbons (CFC’s) etc.
  - Hygienic
  - Involves a natural air cleaning process
  - Reduces dust pollution

**Psychrometric Chart used to measure the achievable Dry Bulb Temperature**

- Source: Renstrom

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**Figure 3:** An example of the “How Does it Work?” assignment

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“thought the unit would be more focused on building environmental services as opposed to 3D modelling”.

Such statements are clearly in opposition to teaching a course favoured by students. In retrospect of these comments, a lecturer might wonder whether the fundamental statement that - “building services are in fact very real entities, take up floor area, volume, and above all, require careful planning within the design concept of the building” (Parlour 2003) - has reached these students.

One of the downfalls might be that Construction Management students are not taught CAD or 3-D modeling programs in the curriculum of the course. Therefore, such students may in fact miss the point that services require spatial planning and that such takes place in 3-D, not 2-D. Nevertheless, there is always room for improvement and the challenge remains in making the delivery of the subject interesting to all.

CONCLUSION
A formula has been presented for teaching a subject which is often perceived as boring, irrelevant and just plain unnecessary by the students. This can be related back to the lecturer’s own university course experiences on such subject matters. By introducing project-based experiential learning, this perception of irrelevance can be overcome. A successful course delivery in building services rests with convincing the student and gaining their confidence that they can and will understand what (at first sight) may appear to be an overwhelming and unconquerable subject.

This unfolding of the subject matter and ‘gaining confidence’ is achieved through the ‘method of investigation’ outline presented in this paper. Perhaps, for the first time, it is not too difficult to convince the students that in order to accomplish the gathering of information they require, they will need to work in groups. An individual group assessment method is not presented in this paper, yet it has been provided in papers elsewhere (Tucker, 2006)

Furthermore, when the students focus on the individual service required, as a segment of a total project, learning occurs from within the group. It was found that the detail of investigation among each service in a particular project increased 3-4 times from when the project was an individual assignment. Even though different information is gathered individually, the organisation of the PowerPoint template, created at the onset of the project, serves as a golden thread in the assembly of the final product and the learning within the group.

It has been noticed that students are often surprised by the actual areas and volume contained by building services. Students gain an appreciation of these services through their own confrontation with building managers, consultants and architects. Although this paper did not cover all the material and assignments taught in the course (such as the peak energy load calculation), it outlined the main course objectives.

The author is most certain that the methods of delivery will continue to be refined and improved; yet, he would highly recommend, and offer to anyone, the approach used and presented in this paper.

ACKNOWLEDGEMENTS
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