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Developing interdisciplinary understanding and dialogue between Engineering and Architectural students: design and evaluation of a problem-based learning module

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Abstract

Engineers and Architects require effective communication and interdisciplinary team working to be successful throughout their career which, is often overlooked during formal undergraduate education. The purpose of this paper is to disseminate the novel design and evaluation of a module on communication and interdisciplinary team working in the combined teaching of undergraduate Engineering and Architecture students. An Interdisciplinary Problem Based Learning (IPBL) approach is used and the theoretical construct for this work is the application of dialogical theory to the shared habitus between engineers and architects. The constructivist theory of learning was employed in the design and delivery of this module. It is an action research pedagogical intervention to support the improvement in the teaching and learning of communications and teamwork between architects and engineers. Feedback shows students identified improvement in their communication and teamwork skills at the end of the module.

Key Words: Communication; Engineers; Architects; Problem-Based Learning.

1.0 Introduction

1.1 Interdisciplinary Project Based Learning

In higher education in recent years, there has been greater interest in interdisciplinary project-based learning (IPBL) (Heikkinen & Isomöttönen (2015)). Students can be directed in an active learning environment to improve their communication skills and enhance their interdisciplinary team working abilities. Educators from many backgrounds have adopted this approach. For example, Lim et al., (2018) examined group interactions occurring between Graphic Design, Communication, Information Technology and Psychology students within an interdisciplinary project. Communication skills were different depending on the discipline, and this did not necessarily mean lack of engagement for ‘quieter’ students. The main finding of Lim et al., (2018) was students had first-hand experience of working with the diversity of groupwork, but also expanded their knowledge outside their own discipline. The authors also reported teamwork skills improving by the end of the module, even though group work attitudes had not changed. Wallin et al., (2017) discuss a large-scale mandatory masters course called ‘Experts in Teamwork’ (2000 students) aimed at interdisciplinary learning and collaboration on a real-world project. Wallin et al., (2017) educational approach was based on experience-based learning and reflections (Andresen, Boud, & Cohen, 1995). Wallin et al., (2017) found that interdisciplinarity drives students’ overall satisfaction of the module and students also increase their perception of the value of collaboration. The authors used a mixed method approach of quantitative analysis (based on student surveys) and textual qualitative analysis (based on differences in project descriptions written by students). The authors state that further study is required to understand the underlying processes for this effect.

In recent years, more and more engineering educators are now including IPBL modules in their curriculum. Engineers and Architects require the skills of effective communication and groupwork to be successful throughout their professional career which, is often overlooked during their formal undergraduate education. Herein, specific reference to IPBL research including Architecture and Engineering disciplines is discussed. Some researchers, such as Jin et al., (2018), have focussed on the use of technology such as building information modelling (BIM) to aid interdisciplinary collaboration. Jin et al., (2018) present a pedagogical approach for assessing students' interdisciplinary building design work adopting BIM. The students included Architecture, Engineering and Construction students and the BIM technology was found to improve communication across disciplines by facilitating information exchange. McCrum (2017) presented an IPBL module between Engineering and Architecture students. The author focused on engaging higher order thinking to enable complex problem solving rather than evaluating communication and groupwork skills explicitly. Ali (2019), did investigate communication and groupwork skills in a study of IPBL consisting of Building Construction, Architecture and Construction Management & Engineering students. The students had to deliver a complex interdisciplinary capstone project. Ali (2019) found that “students expressed more appreciation for each other’s field and expressed interest in learning more about the thought processes of other disciplines” at the end of the module.

1.2 A Constructivism Approach to IPBL

It is widely regarded that theories of learning fall into one of three categories: behaviourism, cognitivism, and constructivism. Constructivism is centred on the idea that new learning is constructed based on prior knowledge and experiences, and therefore is unique to everyone. Richardson (2003) refers to constructive pedagogy as “the creation of classroom environments, activities and methods that are grounded in a constructivist theory of learning, with goals that

focus on individual students developing deep understandings in the subject matter of interest and habits of mind that aid in future learning”. Constructivism is neither a passive process of receiving knowledge nor a stimulus response phenomenon. It is an adaptive activity and an active process requiring building conceptual structures and self-regulation through reflection (Lambert et al. 1995; Maclellan and Soden 2004; Glasersfeld 1995; Yilmaz 2008).

Teamwork and communication skills can be improved in IPBL; however, Architects and Engineers have a special relationship that needs to be understood to aid constructive alignment of learning outcomes with learning strategies. Section 2 discusses this special relationship. The purpose of this paper is to disseminate the novel design of a module on communication and groupwork in the combined teaching of undergraduate Engineering and Architecture students. Section 3 presents details about this module and Section 4 presents the research design of the educational intervention. The theoretical construct for this work is the application of dialogical theory to the shared habitus between engineers and architects. The constructivist theory of learning was employed in the design and delivery of this module. It is an action research pedagogical intervention to support the improvement in the teaching and learning of communications and teamwork between architects and engineers. This paper is intended to be an example of how educators should teach Engineering and Architecture students how to work together, and how to help them communicate and work in teams, founded in best practice pedagogy. Section 5 presents the evaluation of this educational intervention. Section 6 and 7 present the discussions and conclusions, respectively.

2.0 The special relationship between Engineers and Architects

2.1 The historical relationship between Engineers and Architects

To realise projects in the built environment, collaboration between Architects and Engineers is essential. Comprehensive coverage of the historical relationship between engineers and architects is given in (Saint, 2007). One can imagine that in Greek, Roman and Gothic times, the relationship between Architects and Engineers must have been very close in order to create some of the greatest buildings of the European Classical tradition. At these times, the Architect and Engineer was most likely the same individual – the master builder (Macdonald, 2007). The relationship between structure and Architecture was positive; the Architecture was born out of a need to satisfy structural requirements.

Around the time of the Italian Renaissance this relationship began to change, for largely two reasons. Firstly, typical of the Architecture of this era, structural members were increasingly concealed behind ornamentation which caused the structural and aesthetic agendas to drift apart. Secondly, most structural forms were unambitious using masonry wall and timber floor construction which were well understood and presented little challenge to builders.

The distance between the Architectural and Structural agendas was at its greatest towards the end of the 19th century with the development of structural steel and reinforced concrete. With the development of science, art and science split and the Architect withdrew from the scientific circle. The split is evident from the formation of the Society of Engineers of Britain in 1771, the Royal Institute of British Architects in 1834, the Institution of Civil Engineers in 1818 (Margolius, 2002) and the Institution of Structural Engineers in 1908. While Architects were still interested in structure, it was only as a means of realising their designs.

A consequence of the growing distance between the aesthetic and the structure was the continuation of the established way of working in which the Architect behaved very much as the leader of the design team. This meant that Engineers played a secondary role and made little contribution to the visual aspect of a design, a feature which has continued to the present day (Macdonald, 2007).

The objective of the module presented in this paper is to improve the dialogue and communication between the Engineer and Architect during their undergraduate education so that both professions have a mutual beneficial understanding of each other's professions.

2.2 The profile of the stereotypical Engineer and Architect

As a generalisation, Engineers, as a group, can be known for their ability to solve problems and their inability to work well with other people. Engineers most likely have this stereotype based on their typical cognitive style (Witkin and Goodenough, 1977). The typical profile of an Engineer is a person who; (i) excels at problem solving, (ii) dislikes unpredictable situations because of a lack of structure and rules to guide response, and (iii) has been rewarded for being competitive at an individual level in task performance (Seat et al., 2001). The Architect is the one who responds to the human factor in the entire design process; whereas the Engineers take care of the physics of the built environment. These are two quite different functions, which can combine admirably, even in the same person (Corbusier, 2013). The Architect, like the artist, can be motivated by personal considerations whereas the Engineer is essentially seeking to transform the problem into one where the essential properties of structure, material or some other impersonal element are being expressed. This distinction between creation and invention is the key to understanding the difference between the Engineer and the Architect, and how they can both work on the same project but contribute in different ways (Rice, 1994). Saint

(2007) describes the stereotypes of the architect as an artist who makes things beautiful, and the engineer as a technician, who makes things work. Engineers use an abstract language and the notation of mathematics to develop their designs, whereas Architects employ visual language and graphic notation (Peters, 1991). Architect James Gowan (Gowan, 1987) postulated that Architecture was concerned with art, and Engineering with utility. Gowan even stated that ‘when one activity invades the territory of the other, it does so at considerable risk’ (Gowan, 1987). The other dimension to consider is that ‘art is often concerned with deceit and one presumes mathematics is not’ (Gowan, 1987). Engineering must be rational, objective, precise and straightforward and it must practically work. Architecture can hide behind false premise, fashion, style, preconceived ideas and symbols (Margolius, 2002). Efficiency as a structural technician combined with a facility to create structural form does not imply capacity to create Architecture. On the other hand, not many Architects have the control of technical skills necessary for design in the present increasingly industrialised building climate – the Architect’s tools are their Engineering consultants (Price, 1984).

2.3 Recognising the shared habitus of Engineers and Architects

Habitus can be thought of as a social analogy of genetic inheritance. We do not choose to be what we are, but instead, receive a habitus, handed down from previous generations. It is a set of internalized dispositions that incline people to act and react in certain ways. Our habitus generates perceptions, attitudes, and practices. It is at once the filter through which we interpret the social organizing of our perceptions of other people's practices, and the mechanism we use to regulate our actions in that world, producing our own practices. The habitus provides us with a practical mastery of social situations, telling us instinctively what to do. It provides the feel of the social game. When our habitus is correctly adjusted to the social game we are playing, we feel comfortable, natural, at ease; we know how to react; we feel at home. When we move

to another game - a plumber attending a high-society event, a socialite on a building site - our habitus may be inappropriate to cope with the situation, and we feel uneasy, not quite knowing what is the right thing to say or the right way to behave, not quite liking what is going on. All forms of education transmit knowledge and skills, and all forms of education also inculcate some form of habitus. The two functions are inseparable. This identity is modified as we pass through the educational system and as we encounter other individuals throughout our lives (Stevens, 1995).

In the development of a project in the built environment, there are two key professionals involved: the Engineer and the Architect. Each profession has its own occupational sub-culture (or habitus) which tends to produce problems in construction projects. In the construction of the Sydney Opera House, Ove Arup (the Engineer) was appointed directly by the client, rather than by Utzon (the Architect) which was more normal in Australia at the time. This elevated the Engineer's status and the contractual structure conflicted with Utzon's own view of the architect's pre-eminent role and led to misunderstandings between Utzon and Arup in the later stages of the project (Murray, 2003). The evolution of the profession of Architecture and Engineering through time, as well as the profiles of each profession create a situation where Engineers and Architects struggle to communicate effectively with each other despite its clear need. It is imperative to create a shared habitus to overcome this. Architects and Engineers must work closely in developing designs from early concepts through to the final design and construction as 'they are equal parents to their child' (Addis, 1994).

2.4 The importance of effective communication between Engineers and Architects

Effective communication and interaction between Architects and Engineers cannot be underestimated as a key skill to success (McCrum, 2017). In his Key Speech in 1970, Ove Arup, and iconic Engineer discusses the concept of ‘Total Architecture’ at length. This term implies, he says, that “design decisions have been considered together and have been integrated into a whole by a well organised team” (Arup, O., 1979). Engineers and Architects will spend much of their working life on collaborative projects, and it is imperative that as part of their formal training these students get practical experience and are assessed on their ability to communicate and perform as part of an interdisciplinary team. Saint’s (2007) portrayal of the untidy realities of how structures get built is very apt... ‘once we enter into what happens when a structure is really assembled in any age, we find designing and making, architecture and engineering, art and science, muddled up together so constantly and utterly that a once-and-for-all process of disassociation ... appears implausible’. Curiously, for the most part, the educational system separates these two groups completely in their formal training. Much of the discussion in Saint, (2007) appears to have resulted from observations about the relative locations and complete lack of contact between the Departments of Architecture and engineering at Cambridge University. It is so important for students to have the opportunity to work in small groups and for their higher education experience not to consist only of very large group lectures (Barrett, 2017). They need a place where their word can be heard and where they can listen and learn from other students (Barrett, 2017).

Dialogue is an unfolding process, a search or quest for knowledge and understanding (Rule, 2004). Without dialogue there is no communication, and without communication there can be no true education (Freire, 1972). Freire’s concept of dialogic knowing best captures the nature of learning from one another through working on a common problem (Barrett, 2017). Dialogic knowing is the means by which people create and recreate acts of knowledge together as

“dialogue unites subjects together in the cognition of the object that mediates them” (Freire, 1985).

From this perspective dialogue is much more than a technique, it is a position or stance that sees knowledge as not something possessed by the teacher and static but something that is made and remade dynamically by students in tutorials through dialogue (Barrett, 2017). Saint (2007) presents case studies demonstrating how engineers and architects have ‘learned to work intimately if quixotically together, spurring one another on in the grail of innovation’. The intervention proposed in this paper is a space to develop effective communication skills between Engineers and Architects. Except that it is more than just interdisciplinary communication – it is about developing the whole concept of dialogue. This dialogue can promote learning through the waves and oscillations of the conversations students have in their groups on their project work (Barrett, 2017).

It is no secret that the quality of interpersonal, communication, and groupwork skills in Engineering graduates is of concern to both industry employers and Engineering educators. In particular, communication skills and team-working skills are core skills that graduates of the 21st century should possess, according to the National Strategy for Higher Education to 2030 (Hunt, 2011). A common criticism voiced by employers is that new hires do not seem to function well in a team-based environment (Bhavnani and Aldridge, 2000). A recent survey of employers within Ireland on what kind of skills they considered important, found responses that skills such as communication and teamwork are just as important as – if not more important than – Engineering knowledge and methods (Engineers Ireland, 2019). Similarly, the results of a formal survey of 15 aerospace and defence companies that identified industry expectations of new graduates with respect to ABET Criteria 2000 (Lang et al., 1999) suggests that graduates are expected to have performed and demonstrated ability in a team-based experience. Likewise, Architecture graduates are expected to have strong team working skills (ranked 2nd behind

design skills in an architecture employer skills survey (RIBA (2015)). In RIBA (2014), communication skills (ranked 4th) were ranked above problem solving (ranked 5th) and creative thinking (ranked 8th). In another survey, groups of respondents from industry and academia, agreed that the top two skills needed by graduates seeking employment are teamwork and communication (Bhavnani and Aldridge, 2000). To achieve success, today's Engineering and Architecture graduates must be team members who thrive while working with a variety of people having differing social, educational, and technical skills (Seat et al., 2001).

Architecture and Engineering professionals have a shared history and habitus, whilst having different cognitive styles. In the following sections an IPBL module is described that takes into consideration the shared habitus, history and different cognitive styles to best align the learning outcomes of dialogue, communication and interdisciplinary team working with learning strategies.

3.0 An interdisciplinary problem-based learning module for Engineering and Architecture students to develop understanding of the profession, communication and interdisciplinary team working skills

The module is a pro-active intervention to create a shared habitus and a shared dialogue between two distinct occupational sub-cultures (or habitus). The module is designed to break down the barriers in interdisciplinary communication and begin to improve the dialogue between Engineers and Architects. This intervention brings the concept of a shared habitus of effective communication and interdisciplinary team working into the student's formal education and their earliest professional development. In this paper, the authors are adding to existing research on communication and teamwork (Bhavnani and Aldridge, 2000; Seat et al., 2001,

Lin et al., (2012); Wallin et al., (2017); Ali (2019)) through the design and evaluation of this new module.

Table 1. Module Lecture/Tutorial/Task Timetable

Week	Monday 2 Hours	Tuesday 1 Hour
1	<ul style="list-style-type: none"> •Introduction •The who's who of construction projects •Interdisciplinary teamwork: <ul style="list-style-type: none"> ○Task 1: Hitchhikers essay ○Task 2: Icebreaker ○Task 3: Team expectations agreement 	<ul style="list-style-type: none"> •Task 4: Role Play
2	<ul style="list-style-type: none"> •Evolution of Structure and Form 	<ul style="list-style-type: none"> •Task 5: Rubrics •Introduce Project 1
3	<ul style="list-style-type: none"> •Force and Equilibrium 	<ul style="list-style-type: none"> •Task 6: Sketching skills
4	<ul style="list-style-type: none"> •Language of Structures •Introduce Project 2: Quiz 	<ul style="list-style-type: none"> •Tutorial Teamwork for Project 1
5	<ul style="list-style-type: none"> •Materials in Structures 	<ul style="list-style-type: none"> •Choosing Materials
6	<ul style="list-style-type: none"> •Project 2: Table Quiz 	<ul style="list-style-type: none"> •Introduction to Project 3
7	<ul style="list-style-type: none"> •Structural elements and forces •Task 7: Everyday objects - forces 	<ul style="list-style-type: none"> •Bending Moments and Shear Forces in Structures •Task 8: Bending and Shear
8	<ul style="list-style-type: none"> •Load paths •Task 9: Exercise on load paths 	<ul style="list-style-type: none"> •Teamwork for Project 3
9	<ul style="list-style-type: none"> •How Structures Stand Up •Introduction to Project 4 	<ul style="list-style-type: none"> •Task 10: Spaghetti tower challenge
10	<ul style="list-style-type: none"> •Conversations between Architects and Structural Engineers 	<ul style="list-style-type: none"> •Teamwork for Project 4
11	<ul style="list-style-type: none"> •Laser cutter tower testing in Civil Engineering Labs 	<ul style="list-style-type: none"> •Teamwork for Project 4
12	<ul style="list-style-type: none"> •Easter Monday (no lectures) 	<ul style="list-style-type: none"> •Studio time to work on report (Project 4)

This paper presents a problem-based learning module called ‘The Engineering and Architecture of Structures’ that the authors deliver on the Masters in Engineering program ‘Structural Engineering with Architecture’ within the School of Civil Engineering, University College Dublin. This program was initially developed by a colleague Associate Professor, Amanda

Gibney, in response to her perceived need of a program that provided students with a thorough grounding in Structural Engineering in addition to developing a keen understanding of the interface of both Architecture and Building Services.

While the genesis of the module came before us, the authors have fully developed the learning outcomes, teaching and learning strategies, the assessment and the content for this module. While the authors are both engineers working closely with architects with previous experience in professional practice, input was sought and included from the department of architecture in the initial design and ongoing reviews of the module. It was developed to address the ever-present challenges in communication between Engineers and Architects. The module is taught in the second semester by both authors and is taught to Year 1 undergraduate Architecture and Year 1 undergraduate Engineering students. The Architecture students take this module as a core module whereas the Engineering students elect to take this module as an optional module. The Engineering students are general entry for Year 1 and they then choose their specific engineering discipline for Year 2 onwards (they can choose from Biomedical; Chemical & Bioprocess; Chemical with Biochemical Minor; Civil; Electrical/Electronic; Mechanical or Structural Engineering with Architecture). Typically, there are 120 students who take this module; approximately 60 Architecture students and 60 Engineering students. The module is 12 weeks in duration (see Table 1), and detail on the curriculum (see Figure 1) in terms of learning outcomes, teaching and learning strategies, assessment and content are provided in the following sections.

Figure 1: Curriculum Alignment

3.1 Learning outcomes

The learning outcomes for this module have been created with the recognition that significant difference in backgrounds, talents and cognitive abilities of the Engineering and Architecture students. The learning outcomes are also in line with UCD's code of practice (UCD, 2015). As a minimum requirement, Engineering students will enter Year 1 at University College Dublin with a C grade (55-69%) or better in their final second level statewide examinations (Leaving Certificate examination) higher level maths, as well as one or more science subjects. In their statewide examinations, students will have chosen to take higher level examinations which are more challenging and provide higher scores, or ordinary level examinations which are less challenging and provide fewer points. Most of the Architects, however, have only completed Leaving Certificate examination ordinary level maths, and possibly no science subject. Taking this into account, the learning outcomes for this module are as follows:

1. Differentiate between the role of the Engineer and the role of the Architect through group discussion
2. Develop effective communication skills through role-play, debates and group discussion
3. Identify, draw and label the forces in Engineering structures

4. Describe and compare the available materials, and their properties for Civil Engineering projects. Defend the choice of material for a given context
5. Assess structural forms and describe why they have been designed the way they have
6. Assess the stability of different structural systems and subsequently visualise, design and create your own structural model
7. Describe structural failures and how Engineers and Architects learn from these failures

3.2 Teaching and learning strategies

Given that a key learning outcome of this module was to support the development of effective communication and collaboration skills of Engineering and Architecture students, a Constructivist Theory of Learning approach was adopted and interdisciplinary team working and problem-based learning are key learning strategies for this module.

3.2.1 Interdisciplinary team working work

The Architecture and Engineering student teams are tutor-formed, rather than letting students self-select, so as teams would have an even mix of Architecture and Engineering students. Students are typically split into teams of 5/6, each with a mixture of two to three Engineering and Architecture students in each team. A potential future improvement could be to automate the team selection process using Team-Maker CATME (CATME 2020; Layton et al., (2010); Jahanbakhsh et al., (2017)) or else use McCusker et al., (2017) approach of intelligently designing teams to better replicate interdisciplinary working environments and improve student experience. Here, the teams are formed during the first lecture of the semester and do not

change throughout the semester. To support effective teamwork, students are engaged in team activities in the first week of term. The lecturer presents the students with an essay on hitchhikers (Oakley et al., 2004) and request a reflection from each student. This encourages students to think critically about interdisciplinary teamwork, and how they as individuals can contribute. A team policies statement (Oakley et al., 2004) is drafted by each team which sets expectations, provides guidance on effective team functioning, assigns roles and develops strategies for dealing with uncooperative team members. The signed agreement serves two purposes; it sets student-generated expectations that they agree to honour and serves as a ‘quasi-legal document’ so students cannot claim they did not know what they were supposed to do.

3.2.2 Problem-based learning

To create the opportunity of developing a shared habitus between Engineering and Architecture students, having a teaching and learning strategy that involved students working together on projects was decided upon. Students participate in four separate interdisciplinary teamwork projects during this module.

For the first project, students work in their interdisciplinary teams to prepare an A1 size (594mm wide by 841mm high) poster containing five free-body diagrams (see Figures 2 & 3). The project deadline is in Week 3 (12-week duration module). These free-body diagrams are to depict the forces shown in photographs. Four photographs are assigned to each team, and the fifth is chosen by the team to be a ‘showstopper’. For each photograph, students are expected to sketch the geometry, add typical dimensions, add forces and label them (including external forces, internal forces, self-weight and supports), and include any relevant notes that explain their reasoning. The concept here is that students will bring their respective strengths

and weaknesses to the project. The Engineering students are likely strong at working with force-diagrams, whereas the Architecture students are more likely to have strong sketching skills. A key challenge always is to convert a real-world example into a simplified Engineering system and this project focuses on these challenges. It offers the Engineering students the opportunity to demonstrate to the Architecture students the very first steps of an Engineering analysis, and offers the Architecture students the opportunity show the Engineering students how to work on their sketching skills, and at the same time creating a shared habitus.

Figure 2: Student Submission for First Project: A1 Size Poster Submissions on Free-Body Diagrams (a) Sample Poster #1; (b) Sample Poster #2; and (c) Sample Poster #3

Figure 3: Close-up View of One Free-Body Diagram Selected from; (a) Bridge Truss Free-Body Diagram from Sample Poster #1 in Figure 2; (b) Hammer Pulling Nail Free-Body Diagram from Sample Poster #2 in Figure 2; and (c) Cable Car Free-Body Diagram from Sample Poster #3 in Figure 2

For the second project, students participate in a table quiz that takes place in Week 6 (12-week duration module). Questions for the table quiz are drawn from all content delivered to the students in the first half of the semester. The quiz offers students the opportunity to debate their answers amongst team members, as would occur in any typical table quiz. This promotes the opportunity for developing dialogue and a shared habitus between Architecture and Engineering students. Some sample questions used in the quiz are provided in Figure 4.

Round 1: Materials

1. True or false: timber can withstand higher forces parallel to the grain orientation than perpendicular to it?
2. Which of the following has the highest amount of carbon: cast iron, wrought iron or steel?
3. Which of the following materials is the strongest: timber, concrete, steel, masonry?
4. What are the two primary ingredients use in steel production?
5. List the four ingredients in concrete?
6. Name one option for protecting steel from fire?
7. What two things are required for the corrosion of steel to occur?
8. True or false: timber is good in fire?

Round 2: Structural Forms

Label the structural form:

Figure 4: Sample questions used in the quiz on ‘Materials and their Properties’

The third project involves students preparing an A1 size poster in their interdisciplinary teams that investigates and demonstrates understanding of how the loading, layout and Architecture of a structure or part of a structure (e.g. a building, bridge, tower etc) influences the final structural design. The students receive timely feedback on their first submission allowing them time to reflect on the errors they made and improve this poster. The deadline for the third project is Week 9 (12-week duration module). Students are expected to perform a precedence study of five structural types and summarise why they have chosen one type to focus on in detail. The poster should also contain sketches and written description of the structural forms, a description of the loads that are applied to the structure and a description of how the bending moments and shear forces dictated the structure. The sketches allow a common language between Engineering student and Architecture student to be expressed. The concept here is that students will bring their respective strengths to the project. The Architecture students will be familiar with the concept of a precedence study whereas the Engineering students are more likely to have a better understanding of structural forms and bending moments. A key challenge always is to be able to study a real-world example as a simplified Engineering system and this project focuses on these challenges. It offers the Architecture students the opportunity to explain to the Engineering students the importance of precedence studies and offers the

Engineering students the opportunity to demonstrate to the Architecture students the concepts of structural forms, and at the same time creating a shared habitus. An example of a student submissions can be seen in Figures 5 & 6. In general, the layout, presentation and sketching improve notably from the first project poster submission to this poster submission.

Figure 5: Student Submissions for Third Project: A1 Size Poster Submissions on Moments and Shear; (a) Sample Poster #1; (b) Sample Poster #2; and (c) Sample Poster #3

Figure 6: Close-up View of One Free-Body Diagram of Selected from; (a) Sample Poster #1 in Figure 5; and (b) Sample Poster #2 in Figure 5

The final project involves each team designing and developing a scaled model of a tower and to demonstrate how the lateral and gravity loads are transferred to the foundations in the structure. Lateral stability is covered in detail in lecture material. Active learning tasks, such as sketching the lateral load path in a braced frame structure as well as the use of simple physical models to represent shear walls, braced frames and moment resisting frames are used to demonstrate lateral stability concepts to students. Physical testing of the lateral stability as well as the gravity load resistance would be ideal, however it is not possible to do both as seeing physical failure of the structural system is an important learning objective for the students. The fourth project is submitted at the end of the 12 weeks. The idea is to show how the structural skeleton achieves lateral stability and supports the vertical loads. The timber model is made

using the laser cutter in the Civil Engineering laboratory. Students are required to prepare (in advance) a computer aided design drawing of the 2D elements of their structure. Each team is provided with one sheet of timber (Medium Density Fibreboard (MDF)) that is 6.3mm thick and 600mm x 400mm. The students must achieve the tallest, lightest and most load resisting structure possible. Furthermore, students must prepare a report detailing a precedence study for their structure, photographs, a description of their laser-cut tower, details on the lateral stability of the structure and how the vertical loads are transferred to the foundations. The report must also include the description of the failure mechanism. This project is intended to bring together all the learning outcomes of this module and to further reinforce the importance of effective interdisciplinary teamwork and communication between Engineers and Architects. An example of several student submissions being load tested in the laboratory can be seen in Figure 7 (a-c) and two examples prior to testing in Figure 7(d).

Figure 7. Photographs of Laser Cut Model Towers and Load Tested in Week 12 in the Civil Engineering Laboratory; (a-c) During Testing and (d) Prior to Testing

Each of the projects built upon the learning outcomes of the previous project. All the projects were submitted and assessed as a team. Students were responsible for subdividing their own work and were given responsibility to manage their own workloads.

3.3 Assessment and Feedback

Students complete four assessment tasks in this module – which are directly related to their problem-based learning. Students are assessed on their output from each project. The assessment task, the learning, the weighting of each assessment task and the timing, are given in Table 2.

Table 2. Student Projects – Assessment Tasks

Assessment of Project	Learning	Weighting	Week
Poster	Forces and Equilibrium	20%	3
Quiz	Materials and their Properties	25%	6
Poster	Moments and Shears	25%	9
Laser-cut model and lab structural testing	Stability	30%	12

Figure 8: Rubric Criteria

Figure 9: Rubric Cards given to Students

Rubrics were created for each of the assessment tasks in class with students (Figure 8 is for the first project). Each team was given an envelope of cards. Each card contained an assessment criterion on one side and its definition on the reverse (see Figure 9).

Students spent time within their interdisciplinary teams deciding the criteria and respective weighting to be used in the rubric. This approach achieves buy-in from students in the

assessment process, a greater understanding of the expectations for the assessment, as well as getting students started much earlier (Gibbs and Simpson, 2005). This approach also supports students engaging in a discipline that is less familiar to them, i.e. Architecture students experiencing more Engineering types of concepts and practices. Furthermore, the activity achieves the objectives of being transparent, inclusive and empowering students to be self-regulated learners.

The feedback strategy for this module included delivering feedback to students in a timely manner, ideally within 2 weeks (UCD, 2015). According to (Gibbs and Simpson, 2005), if students do not receive feedback in a timely fashion then they will have moved on to new content and the feedback is irrelevant. They will become demotivated and lose faith in the assessment system (Flint & Johnson, 2011). In this module, timely feedback allows feedforward (Orsmond et al., 2013) for future assessment. Feedback sheets were developed and completed, and students received commentary on their work, as well as a grade within two weeks of their submission. An online virtual learning environment called Brightspace is used for feedback, although many other technologies are available to facilitate and improve assessment exist, such as Deeley (2018). Feedback was sensitive to the unsophisticated conceptions of learning that students may have (Gibbs and Simpson, 2005). A grade on its own is likely to be perceived by a student as reflective of personal worth (Gibbs and Simpson, 2005). According to (Boud et al., 1999), assessment has most effect when students receive specific information about how to improve the quality of their work, correct errors and re-orient their efforts. Some feedback was given as whole class feedback, as suggested by (Hornby, 2003). Sambell et al., (2019) states that we should rethink assessment such that learning, rather than focusing on measurement and quality assurance. The assessment for learning ideal (Boud & Falchikov, 2007)) of stimulating student engagement is practiced here in this module.

3.4 Alignment of learning outcomes with assessment tasks

Given that students will focus their study efforts based on the assessment tasks it is important to have constructive alignment (see Table 3) between the learning outcomes and the assessment tasks. Early assessment provides information to both students and teachers on progress and achievement and allows for identification of students in need of additional support. Maintaining motivation is most important for a first assignment in first year (Gibbs and Simpson, 2005) and so the first assignment is weighted less than the subsequent three (refer to Table 3).

Table 3: Constructive Alignment of Learning Outcomes with Assessment Tasks.

Learning Outcomes	Project 1: Forces & Equilibrium (20%)	Project 2: Materials & their Properties (25%)	Project 3: Distributions of Moment & Shear (25%)	Project 4: How Structures Stand up (30%)
1				
2				
3				
4				
5				
6				
7				

3.5 Content

The content of the lectures was developed last, after the learning outcomes, teaching and learning processes and assessment tasks. An overview of the lecture content delivered to students is given in Table 1. The following is a description of the formative tasks in which interdisciplinary teamwork and communication skills are encouraged in the students. They serve as a sample of the approach taken throughout this module. As per Table 1, these tasks all take place within Week 1.

Task 1: Hitchhikers Essay

A lecture was created in which the term 'hitchhikers' is explained to all of the students. It is explained that 'hitchhikers' are team members who refuse to do their share of the work but get the same grade as their more responsible teammates. It is also explained that 'hitchhikers' can also be domineering team members who try to coerce the others into doing everything their way. They can also take the form of resistant team members who resent having to work in a team and refuse to participate. The lecturer also explains that team members can have widely divergent goals – some want an A no matter what it takes and other might just want to do enough to get a C. Students are then presented with a short essay on 'hitchhikers' and an individual reflection is requested from each student on this as suggested in (Oakley et al., 2004). Students submit the reflection online through Brightspace and the next set of notes will not become available to them until they have completed this submission. This task is not graded.

Task 2: Ice Breaker

Given that students will spend the semester working in their teams, time is set aside at the start of the semester to allow team members to get to know each other. In their interdisciplinary teams, each member is asked to introduce themselves to their team (e.g. their name, where they are from, what subjects they studied in school, and whether they are an Engineering or Architecture student). The Engineering students of the team are asked to explain Engineering to the Architecture students, and likewise the Architecture students to explain Architecture to the Engineering students. The students are asked to discuss what Engineers are typically good at, and the same for Architects. Students are then asked to discuss ideas of how these professions can work best together. Students are expected to summarise their discussion as a team and submit it online through Brightspace. As before, the next set of notes will not become available to them until they have completed this submission. This task is not graded.

Task 3: Team Expectations Agreement

Within their interdisciplinary teams, students are requested to prepare, sign and submit a ‘team expectations agreement’, as suggested in (Oakley et al., 2004). The agreement serves as a pseudo-legal document to prevent anyone from making invalid claims about what they were supposed to do. It is intended to unite the team with a common set of realistic expectations that the members generate and agree to honour. In preparing their agreement, students are encouraged to consider outlining team roles and their responsibilities, procedures for working on submitting assignments, strategies for dealing with uncooperative team members, effective team functioning, and expectations for team meetings. It is important to make sure students are aware of the consequences of non-engagement with teamwork activity and address this in the assessment setting. This task is not graded.

Task 4: Role Play

Role play is a technique that allows students to explore realistic situations they will encounter in their future careers. Students are asked within their teams to arrange themselves so that the Architecture students are on one side of the table and the Engineering students are on the other side. Each set of Architecture students, and separately each set of Engineering students, are presented with a description of a role they need to act out in relation to a building project. Each set of Architecture and Engineering students are allowed 3-5 minutes to discuss the arguments they are going to make. When they are ready – they then engage in a debate across the table about what they should do. The purpose of this task is to encourage students to play out their roles in an educational environment to support their learning and understanding of interdisciplinary teamwork and communication. This task is not graded.

4.0 The research design of the educational interventions

This is an action-research pedagogical intervention designed with the purpose of creating an environment where team members need to cooperate. The design of the educational interventions in this paper were largely driven by examining best practice in the literature on assessment and teamwork.

4.1 Assessment

Effective learning is often hampered by assessment tasks that focus student attention on ‘reproductive thinking’, where students memorise content and regurgitate in exam settings (Boud and Dochy, 2010). According to (Gibbs and Simpson, 2005), assessment should be designed to support worthwhile learning. It should be considered from the outset of the module design, and not included as an ‘add-on’ (Boud and Dochy, 2010). They argue that standards will be raised by improving student learning rather than by better measurement of limited learning. Students cannot develop ethical awareness by being told about ethics; rather they must learn to evaluate situations from an ethical perspective and make ethical decisions (Nicol, 2014). Similarly, students cannot develop communication skills by being told about them – they must learn to evaluate the quality of their own communications and those received from others.

The module presented in this paper is a compulsory 5-credit module for Architecture students. At the same time, these students complete a 20-credit module in studio design which involves contact hours of approximately 30 hours per week. Subsequently, the lecturers on this module in the past have found these students difficult to engage. The Architecture students tend to prioritise their studio work above all else. There is a temptation to increase the summative assessment aspects of the module to remedy this. Such an approach has been noted in the literature by (Gibbs and Simpson, 2005) who argue that ‘you have to assess everything that

moves in order to capture students time and energy'. As a result, the number of assessments in a module is often determined by the assessment loads in other modules of the same programme (Harland et al., 2015).

On occasion during this module, Architecture students have excused themselves from class to cope with their other coursework. There is a temptation to control student's study behaviour and to reward their work with summative grades. According to Harland et al. (2015), this type of behaviour can lead to a 'grading arms race' between academics and modules where both lecturers and students seem trapped in a system that would inevitably escalate grading frequency (Harland et al., 2015). The grade has become a proxy for an education.

It is clear that assessment tasks can generate unhelpful and inappropriate learning activity that mis-orient student effort (Gibbs and Simpson, 2005). Students often find the idea of going beyond the syllabus foreign and seem to have relinquished the right and opportunity to take responsibility for their learning (Harland et al., 2015). Assessment will have most effect when students progressively take responsibility for assessment and feedback processes, and developing their critical thinking abilities, including self-critique (Boud and Dochy, 2010).

Students are often 'strategic learners' (Harland et al., 2015); where it is the assessment, not the teaching, that has the greatest influence. Students are quite talented at sifting through the course content, filtering out what was needed, and as a result do well in all modules. Students often have an unsophisticated conception of learning (Gibbs and Simpson, 2005). There is a belief amongst students that there are an enormous number of correct answers and their role is to memorise these and regurgitate them back in exams. Sometimes, academic tasks make little sense to students. They may not always understand, for example, the purpose of completing laboratory reports, especially when it has already been written hundreds of times before in the

same format (Gibbs and Simpson, 2005). It is important that students learn and develop lifelong learning skills, as opposed to just ‘memorise’ and perform during examinations.

The concept of ‘slow scholarship’ as proposed by (Harland et al., 2015), where larger, more integrated assessment tasks are used that take many weeks to complete (rather than days) is adopted here. (Boud and Dochy, 2010) argue that learning is enhanced when assessment tasks require substantial involvement over time which promotes deep learning. The kind of learning that coursework involves has long term consequences while the kind of learning involved in revision for exams does not (Gibbs and Simpson, 2005).

Therefore, this module was set up as entirely continuous assessment rather than standard examination assessment. The assessment would be done in interdisciplinary teams as to improve the student’s communication skills. Each of the four main assessment submissions during the semester would build on the previous assessment and improve the engagement and communication between the Architecture and Engineering students. The assessment submissions were all IPBL projects as to prevent reproductive thinking and remove the possibility of strategic learning.

4.2 Interdisciplinary Teamwork

In modules where team performance becomes part of the evaluation process, the student must master an entirely different set of abilities that demonstrate knowledge by; (i) being a team member and cooperating in a team, (ii) helping to plan, (iii) pacing and scheduling projects, (iv) getting peer and teacher feedback on work, and (v) teaching classmates. In traditional education, the individual has control of performance and outcomes. However, in teamwork, the individual loses control in favour of the team (Seat et al., 2001).

According to Oakley et al., (2004), where learning involves teamwork, students achieve higher grades, learn at a deeper level, retain information longer, are less likely to drop out of education, acquire greater communication and teamwork skills, and gain a better understanding of the professional work environment. What is particularly interesting is the assertion by (Gibbs and Simpson, 2005) that the quality of the team product (such as a report) that is marked may be less important than the qualities of the learning process that created it.

If students self-select, strong students will congregate, and as a result, so will teams of weak students. Teams of strong students tend to adopt a ‘divide and conquer policy, parcelling out and completing different parts of the assignment individually and putting the products together without discussion’ (Oakley et al., 2004). Therefore, the authors have chosen to select teams rather than letting students self-select.

5.0 The evaluation of the educational interventions

Evaluation of the educational interventions was through student surveys where qualitative and quantitative feedback was gathered from students twice during the semester, at the midpoint and at the end of the semester in two consecutive years (2018 and 2019, Ethical Exemption Number: LS-E-19-38-Keenahan). Guskey (2000), a leading author in the field of educational evaluations, describe five levels of evaluation from simple to more complex. With each succeeding level, the process of gathering evaluations requires more time and resources and each higher-level builds on the ones that came before. The first level of evaluation is “*participants reactions*”. It is the most common form of evaluation, the simplest, and the easiest type of information to gather and analyse. Questionnaires typically include a combination of rating-scale items and open-ended response questions that allow participants to provide more personalized comments. Given the limitations on time and resources, it was

decided that gathering participant reactions through student surveys was the most appropriate for this study.

Figure 10 illustrates the demographics of students who were registered to this module. In 2018, there were 103 students registered (59 from architecture and 44 from engineering). Of these, 58 identified as male and 45 identified as female. In 2019, there were 121 students registered to the module (60 architects and 61 engineers). Of these, 48 identified as female and 73 identified as male. Of the 224 students who took the module over the two years, students were citizens of 19 different countries (192 Irish and 33 International students). Over the two years, there was a response rate of 60% (135 out of 224) at the midpoint of the semester, and a response rate of 52% (117 out of 224) at the end of the semester. On reflection, the authors were pleased with the response rate, and attribute the lower response rate at the end of the semester to student pre-occupation with examinations. Analysis of the quantitative and qualitative feedback from students are provided in the following sections.

Figure 10: Demographics of students registered to the module.

5.1 Quantitative Feedback

Students were asked to score their response (from 1 to 5) to three questions relating to communication and interdisciplinary teamwork at the midpoint of the semester. A score of 5 indicates a ‘very positive’ response and a score of 1 indicates ‘very negative’ response. The three questions were as follows:

1. I understand more about the relationship between Engineers and Architects after taking part in this module?
2. How much did you develop your communication skills during this module?
3. Did the interdisciplinary teamwork help to develop working relationships with the other profession (Architects/ Engineers)?

In all cases, the results presented are averaged over the two consecutive years. An analysis of the data from each separate year, found the results were very similar. Figure 11 shows student responses to the question ‘*I understand more about the relationship between engineers and architects after taking this module*’. The results strongly indicate that Engineering and Architecture students have gained important knowledge, understanding and appreciation of each other’s professional relationship (on average 4.1/5 for the Engineers and 3.8/5 for the Architects). Given that this is a key learning outcome of the module, and that understanding is a key component of learning, the authors were pleased to see such a positive response to the improved understanding of each other’s profession. Reflecting on the literature and the historical relationship between engineers and architects, the authors are pleased that this key outcome has been achieved. It also aligns well with Ali (2019) who also reports that Building Control/Construction Engineering and Management students have a better understanding of the Architecture student’s role in an interdisciplinary building project.

Figure 11: Results of Question 1

It is interesting to note that students report the same (Architects 3.8/5) or marginally less (Engineers 4.15/5 down to 4/5) understanding of the working relationship between Engineering and Architecture students between the midpoint of the semester and the end. While on the surface, this may seem like a disappointing result, the comments gathered in the surveys (discussed in Section 5.2) reveal that as the module went on, students gained a greater understanding of the complexities and challenges of working together.

Figure 12 presents the student responses to the question ‘*How much have your communication skills developed so far?*’. The results suggest that students have learned the importance of effective communication (on average 3.4/5 for the Engineers and 3.4/5 for the Architects). Supporting the effective communication and dialogical skills of students is a key learning outcome of this pedagogical intervention. The authors were pleased to see the positive responses from students. Reflecting on the historical relationship between architects and engineers and how it can lead to challenges on projects (for example the Sydney Opera House), the authors are pleased that students have engaged well in developing their communication skills.

Figure 12: Results of Question 2

All students report similar levels of development in their communication skills at the midpoint of the semester and the end.

Figure 13 shows student responses to the question ‘*Did the groupwork help to develop working relationships with the other profession?*’. The results are positive and suggest that both Engineering and Architecture students have gained understanding and appreciation of the importance of teamwork (on average 3.7/5 for the Engineers and 3.8/5 for the Architects). High-functioning teamwork is a learning outcome of this module and the authors are pleased that students have developed their skills in this area. Reflecting on the literature discussing the shared habitus of engineers and architects, the authors are pleased that students have engaged well with the teamwork activities of this module.

Figure 13: Results of Question 3

It is interesting to note that overall results from all students are similar at that there is no obvious distinction between engineers and architects. On reflection, it is worth remembering that Architecture students take this module as a core module whereas the Engineering students elect to take this module as an optional module. This appears to reflect a balance in how the module has been designed and implemented.

On reflection, Projects 3 and 4, alongside Tasks 7-10 that occur after the mid-semester survey, have a greater focus on technical learning as opposed to interdisciplinary teamwork and communication. This should be taken into account when reading the results of Figures 11-13 on student awareness of relationships, teamwork and communication.

Based on the results in Figures 11, 12 & 13, the students have reached the objectives of improving their communication skills, understanding more about the other student's discipline and students felt the teamwork helped to develop a relationship with the students from the other discipline. Overall, the authors believe that the educational interventions discussed in Section 4 have been effective.

5.2 Qualitative Feedback

In addition to the quantitative data collected, students were also asked to comment on ‘*key things learned from the other profession*’ as part of the survey. The following sections reflect on the student commentary from the engineers and from the architects, both at the midpoint, and at the end of the module.

5.2.1 Comments from Architects

A common theme in the written comments from the Architecture students at the midpoint of the module in relation to ‘key things they have learned from the Engineers’ referred to their (the Engineers’) comprehensive understanding of maths and physics. Several other Architecture students noted their ability to think logically. Another common theme focused on the importance of being flexible in their thinking. At the end of semester survey, on average, 41% of Architecture students wrote a comment on the survey. Of these students, 34% commented on communication skills, 41% on the Engineering student’s technical knowledge, and 25% mentioned teamwork. A sample of both positive and negative comments from students are presented in Figure 14 with further samples provided in Appendix A.

Figure 14: Sample commentary from Engineers and Architects

5.2.2 Comments from Engineers

Some comments from the Engineering students at the midpoint of the module in relation to *'key things they have learned from the Architects'* referred to their (the Architects') interest in and ability to prioritise aesthetics and design. Another common theme was the role architects have in working with their clients, and the importance of working well with them. At the end of semester survey, on average 49% of the Engineering students that wrote a comment on the survey in relation to *'key things they have learned from the Architects'*, 21% commented on communication skills, 51% on the Architecture student's creativity/perspective, and 20% mentioned teamwork. Further examples of comments made by Engineers are Given in Appendix B.

5.2.3 Reflections on Student Comments

Reflecting on the comments from students, it is clear that the historical relationship between engineers and architects, and their stereotypes still prevail. The feedback shows that the students have developed an understanding of each other's discipline and have developed their communication and teamwork skills. This aligns with similar findings in the literature by Ali (2019) who demonstrated that most of their Engineering students showed an appreciation for how architecture students approached a design problem. The student comments demonstrate that the learning outcomes of the module were achieved. On reflection, it is worth noting that overall, the comments are very positive considering that a response was voluntary in relation to teamwork, communication and how they saw each other's profession. Reflecting on the assertion by Gibbs and Simpson (2005) that often the quality of the group product (such as the posters or the tower) is less important than the qualities of the learning process that created it, the authors are further encouraged by the positive comments from students on groupwork.

It should be noted that there are clear limitations in relation to students self-reporting (answers tend to capture whether participants *liked* the content) and potential for socially desirability responding and confirmatory bias by authors. The research design for the study was in gathering '*participant reactions*' (Guskey, 2005) which are at level one out of five in the hierarchy of levels of evaluation information.

6.0 Reflections and Discussion

Reflecting on the assertion by (Brookfield, 1995) that cautions educators not to 'teach innocently' is extremely relevant and that one of the hardest things for teachers to learn is that the sincerity of their intentions does not guarantee the effectiveness of their practice. Stemming from this concept, the authors have endeavoured to engage in the process of reflection on all

of the teaching and learning experiences related to this paper. Following the creation and implementation of this pedagogical intervention, a key finding identified is the development of empathy in students. Architects could better empathise with the engineers and vice versa due to the interventions and this is significant. This is evident in both the quantitative feedback and qualitative feedback from students.

The authors have several other reflections:

- The students engaged well with all the activities (teamwork, tasks and activities etc)
- The length of time designated for each part of the module was appropriate.
- The sessions ran smoothly due to the preparations done for the module, including printing and laminating materials for students
- Formative assessment such as the tasks undertaken during the module e.g. hitchhikers task, ice-breaker task, team expectation agreement task, etc, encouraged the students to be reflective learners.
- The assessments and feedback strategies improved the student's communication and interdisciplinary teamwork skills.
- Both sets of students showed good demonstration of their understanding of what the other profession did.
- Both sets of students learned about the other profession and notably demonstrated this with their written feedback.
- Most impressively, when the students from both disciplines were asked about their understanding of the relationship between Architecture and Engineering students, both gave very positive responses and an increase in the positivity of the response over the duration of the module.

- The authors believe the outcomes were achieved through a clear statement of the learning outcomes, constructive alignment of the learning outcomes with the assessment tasks, careful planning of the tasks and activities in the module, and effective delivery of content to students.

7.0 Conclusions

The purpose of this paper was to disseminate the design and evaluation of a module on communication and interdisciplinary teamwork in the interdisciplinary teaching of Engineering and Architect students. The theoretical construct for this work is the application of dialogical theory to the shared habitus between engineers and architects. The constructivist theory of learning was employed in the design and delivery of this module. It is an action research pedagogical intervention to support the improvement in the teaching and learning of communications and teamwork between architects and engineers. Learning strategies, founded in good pedagogical practice, to improve the communication between Engineering and Architecture students as well as the awareness of the others' profession were presented. The strategy of aligning learning outcomes to develop communication skills and prevent reproductive learning were applied in four group continuous assessment problem-based learning submissions. The strategies were applied in the experimental setting of a Year 1 undergraduate module jointly offered to Architecture and general entry Engineering students at the School of Civil Engineering, University College Dublin. Overall, the feedback from the students from both disciplines was very positive. Results from surveys showed the students enjoyed the module and had a high level of understanding of the other profession at the end of the module. The students identified an improvement in their own communication skills and interdisciplinary teamwork as a result of the module.

Overall, this study makes a novel contribution to the literature in the careful design and implementation of a module that addresses interdisciplinary communication and teamwork

skills, where evidence of a deficiency of these skills is in abundance. In the practice of Engineering Education, the study is a novel contribution to IPBL where there has been very little published research in this area. Similar work could be undertaken by others to validate these findings and potentially to improve the student experience. Engineering and architecture graduates who have taken this module will, in their formal education, have experience of working and communicating with each other, which will be of huge benefit in professional practice.

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Appendix A – Comments from Architecture Students

Comments from the Architecture students in relation to ‘key things they have learned from the Engineers’ at the midpoint of the semester include:

- ‘we must be reasonable, understanding, open minded and willing to adjust’
- ‘we must be patient with them’
- ‘the importance of compromise and good communication’
- ‘the ability to compromise a design for structural enforcements and the ability to understand their points of view’
- ‘teamwork’
- ‘they showed a low appreciation of the value of Architects in design and construction. We don't just make things look pretty as they seemed to think’
- ‘they have no imagination and don’t care about beauty’

A sample of comments from the Architecture students in relation to ‘key things they have learned from the Engineers’ at the end of the semester include:

- ‘Engineers think a lot differently to Architects and are bringing very different skill sets’
- ‘It’s important to listen to comments Engineers make early in the design of a project because they understand how structures work. They have, for the most part, very little interest in the design of a project in comparison to the structure and so Architects need to work hard to push their ideas’
- ‘The role of Engineers in the building industry. What skills they have in comparison to Architects’
- ‘The role of communication between the two during the process of designing’
- ‘Start from the beginning - everything will be clearer if conversations start early’
- ‘It’s important to be vocal and make yourself heard’
- ‘Compromise, cooperation and teamwork’

‘There is a strong relationship between the two professions, and we will always be working alongside each other’

‘Teamwork is better than working alone’

‘Communication, understanding and teamwork is very important for project work to be successful’

‘A good relationship between Architect and Engineer is most important to a building that anything else’

‘Engineers like simple structures’

‘Types of structures, the importance of communication skills, an awareness of how everyone has different skills and how that should be used to benefit the project’

‘How to share ideas and the areas of knowledge we each have with each other’

‘The importance of working together for the best interest of the client’

‘I learned about the different ways in which we think and learn to better understand the through process of Engineers’

Appendix B – Comments from Engineering Students

Comments from the Engineering students in relation to ‘key things they have learned from the Architects’ at the midpoint of the semester include:

- ‘I learnt where the Engineers and Architect’s knowledge differ, Engineers cannot properly design a building. Architects knowledge of forces are limited’
- ‘It’s a good indication of who we are working/ studying with for next three years’
- ‘We don’t have the same line of thinking’
- ‘They are creative’
- ‘They have their own requirements for structures irrespective of safety and strength’
- ‘That Architects and Engineers are very different people’
- ‘Architects work closely with the client’

A sample of comments from the Engineers students in relation to ‘key things they have learned from the Architects at the end of the semester include:

- ‘How to adapt Engineering principles to aesthetic design’
- ‘Both have different priorities although both want the same end result’
- ‘Knowing buildings must have elements of style rather than being purely structurally based’
- ‘Architects philosophies are visualising a structure and Engineer will rely on logical standpoints and reasoning to make the structures’
- ‘They are more interested in design than structural soundness’
- ‘How to work together and understand our differences and strengths’
- ‘Learned to view work from their perspective’
- ‘The different roles Engineers and Architects play in projects’
- ‘Communication is key. Drawings help understanding’
- ‘We learned that Architects see structures from a much different perspective’

‘The importance of compromising/ group organisation/ other methods of approaching tasks’

‘Reasoning is a must from both sides’

‘Patience’ (the respondent did not elaborate on this comment, but it is assumed to relate to learning to be patient from the Architecture students in their groups)

‘Improving the design of structures. How to cooperate and come to a compromise between stability and design’

‘They are given design requirements by their clients; they create their own image of what that room/building will look like however it may not always be physically possible’

‘You must compromise, you must communicate your ideas clearly and visually, so everyone understands’

‘Communication and deadline setting are very important’