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MPBL Aalborg

The Secret of their Success!

Semester 4 Thesis – Project Report

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NUI MAYNOOTH
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Foreword

'Teaching and Learning in higher education is a shared process, with responsibility on both student and teacher to contribute to their success' [European Commission 2013].

One way to encourage students to take on their share of this responsibility may be to seek their views on the factors which they themselves feel contribute to their success. In this study over fifty engineering students are asked directly what the concept of success in engineering education means to them.

'In general, interdisciplinary and multi-disciplinary approaches appear increasingly popular in higher education curricula, together with entrepreneurial, intercultural and working world experience. In teaching, the focus is put on students' learning processes – especially with the increasing use of PBL' [OECD 2014].

The students who participated in the study spanned a range of cultures including Irish, Chinese, Danish and Brazilian who had experienced PBL primarily engineering but also in a range of engineering related disciplines including product design and architecture.

'Problem-Based Learning (PBL) has been demonstrated to encourage greater student engagement and leads to better learning outcomes' [European Commission 2014].

The opinions of the above heterogeneous selection of students with experience of PBL are also gathered in relation to the characteristics of PBL which they attribute to their success in their engineering education.

Acknowledgements

I'd like to say a very special thank you to Prof Lars Peter Jensen of Aalborg University for opening my eyes to the power of PBL and also for being such a great host when myself and two colleagues visited the University in June 2012 to see first-hand how best to integrate PBL into an engineering education.

My heart-felt gratitude is also due to both Prof Erik de Graaff and Prof Mona Lisa Dahms who were my facilitators during my semester 4 project. Their support, prompt and constructive feedback and encouragement throughout was excellent. They both made me realize the value of an experienced facilitator.

A special thanks also goes to Dr Alison Farrell from our Centre for Teaching and Learning for facilitating the student focus group. Her ability to get right into the minds of the students and draw out the fine detail of their PBL experience resulted in really valuable data.

Finally, many thanks to all the students who participated so enthusiastically in the study. I couldn't have done it without you!

Abstract

Much has been written about the benefits of active learning. The majority of this literature comes from the teaching community and as such often gives the educator perspective. In this study, the decision was made at the outset to prioritize the perspective of the learner via the following research question:

What characteristics of PBL (if any) do successful students attribute to their success on an engineering programme?

The research instruments used in the study consisted of an initial short student questionnaire to gather both quantitative and qualitative feedback followed by a focus group which was designed based on the questionnaire feedback. Fifty-three students completed the initial questionnaire and five of these participated in the follow-up focus group which was independently facilitated. Although the sample size is too small to draw statistically strong conclusions, the findings nonetheless indicate that the students experience of PBL is generally very positive and further that 60% of them attribute their success on the engineering programme to the teamwork characteristic of PBL.

As a result of this teamwork finding we also revisited the PBL literature with a re-focus on the teamwork characteristic and summarize the current thinking, recommendations and open issues to be considered for the effective integration of teamwork and PBL into an engineering programme.

Contents

• Preface

Sometimes a chance conversation can have a major influence on your life! We've very little control over the time or place of such encounters but we can always be alert to them and ready to act accordingly. And remember, it's better to regret trying something than to regret not trying it.

In November 2011 Prof Lars Peter Jensen from the University of Aalborg visited NUI Maynooth and facilitated two Aalborg PBL model workshops, one aimed at a University-wide audience and one customized specifically to the Department of Electronic Engineering. Following the second of these workshops, myself and two colleagues joined Prof Jensen for lunch and in the course of the conversation he happened to mention that in his experience of PBL in engineering education the single most influential element of this educational model was the peer-learning.

I've been lecturing in engineering education for twenty-five years now having previously worked in the UK and Japan. I sometimes wonder did my time in Japan sensitize me to the power of teamwork as they seemed to use it to very good effect. If my time there (I spent two and a half years working in Atsugi, Sony's largest global R&D centre with over 5000 engineers) did sensitize me then it took me a long time to act on it. I had heard of 'the Aalborg experiment' during the nineties but never took the time to look into it. Maybe I was always too busy with my 'research'. Maybe it was a combination of the earlier Japan experience followed by a growing dissatisfaction with my lecturing and the sense that there must be a better way to help prepare my students to become good engineers than presenting them with lots of information and testing how much of it they could reproduce in an exam.

So following the encounter with Prof Jensen I started the change to PBL. My only regret is that I didn't do it years ago. Still, better late than never! I wouldn't say that I'm fully there yet but I'm happy that I'm moving in the right direction and a growing number of my colleagues are moving with me.

One of the findings of the study is the value of a good facilitator in PBL best practice. Of course this isn't a new finding as it's already well documented in the literature. However, in the course of this study I was very fortunate to have two extremely helpful facilitators, namely, Prof Erik deGraaff and Prof Mona Lisa Dahms. Initially Prof deGraaff acted as my facilitator but unfortunately due to unforeseen family circumstances he had to take special leave from April 2016 at which time Prof Dahms took over as my facilitator. It's amazing how much more meaningful such a finding becomes when you experience it rather than just read or hear about it. But then I guess that's what PBL is all about – experiential learning!

Bob Lawlor

1.0 Introduction

Education in our times must try to find whatever there is in students that might yearn for completion, and to reconstruct the learning that would enable them autonomously to seek that completion.'

Allan Bloom (1930-1992)

Over the past fifty years Problem Based Learning (PBL) has gained widespread acceptance as an effective method in medical education [Spaulding 1969, 1991; Barrows 1972, 1996; Jones 1984; Muller 1984]. It has also received much interest from educators in other disciplines such as law, science, engineering and business [Boud 1991]. Our primary interest is in the effective use of PBL in engineering education and we are fortunate that much too has been written by experienced practitioners about how best to implement PBL in this discipline [Woods 1994, 2000; Graaff & Kolmos 2007; Moesby 2004]. Comprehensive studies have also been undertaken to gauge the opinion of employers relating the attributes of graduates of PBL programmes [IFO 2004, Kjærsdam 2004] and their level of preparedness to succeed in the workplace. These studies have indicated that the attributes of PBL graduates are well in line with the requirements of the workplace. In this study, therefore, we[1] decided to focus our attention on students who have experience of PBL in their engineering education and in particular to try to identify the specific aspects of PBL which they felt were most influential in their successful progression through their programme. This in turn led us to frame the above area of interest into the following research question:

What characteristics of PBL (if any) do successful students attribute to their success on an engineering programme?

There are a number of stakeholders associated with the concept of 'success in engineering education'. The majority of the literature relating to indicators of such success appears to be based on the engineering educator perspective and the employer perspective but not so much on the student perspective. Some might argue that students would not have sufficient training and/or experience to offer an 'educated' perspective on the matter. A similar argument is often presented in opposition to the use of self- and/or peer-assessment in higher education and yet research has shown that careful integration of such assessment techniques in a range of disciplines including Engineering [Dochy (1999), Cowan (2004), Parmelee (2012)] can significantly enhance student motivation and achievement of learning outcomes.

If we wish to adopt a student-centred stance on researching this concept then one could argue for prioritizing the student as one of these primary stakeholders. Therefore, as outlined in the research question, the focus of this study is to gain some general insight into student

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interpretation of success in their engineering education and specifically to investigate if they attribute this success to their experience of PBL in their engineering education.

The neutral reader might legitimately ask if the above research question is biased in favour of PBL. It is widely accepted among the higher education community and beyond that careful alignment of all elements of any programme of education is more likely to result in deeper learning of the learning outcomes [Biggs 1996]. In his more recent analysis of *'what the student does'*, Biggs goes further to say that *'Problem-based learning is alignment itself'* [Biggs 2012 p.50]. Therefore, we feel that the above research question is justified and might even complement Biggs' constructive alignment theory by exploring what the student thinks in relation to their own successful achievement of learning outcomes and important skills development and the role (if any) which PBL played in this success.

Case (2014, p. 727) notes that *'we need to understand in more depth what actually takes place in real engineering classrooms, particularly when we are implementing innovative pedagogies'*. Our research question could be viewed as a subset of Case's open issue in engineering education in the sense that we are looking to understand in more depth what actually takes place in PBL group projects.

2.0 Problem analysis

An important first step in addressing the above research question is to first define our terms of reference associated with the key concepts which are central to the research question. The over-arching key concepts are:

- Engineering education and
- Problem Based Learning (PBL)

Obviously these over-arching or macro concepts are very broad and need to be systematically broken down into their sub-parts which are more directly related to the research question. The concept of *'success in engineering education'* is central to our study but we need to be careful in how we define the term 'success' in this context.

'In the descriptions of learning analytics we talk about using data to "predict success". I've struggled with that as I pore over our databases. I've come to realize there are different views/levels of success … I have started to model metrics and I haven't come to any solid conclusions yet. It really boils down to who you are and how you define success. Different parts of the institution will have different definitions.' [Sharkey 2010 01/09 posting].

Sharkey makes an important point in relation to the concept of success in that it might well have different interpretations for the different stakeholders. Rather than defining 'success' at this point from our (the educator) perspective, instead we look to identify the primary stakeholders associated with our research question and to investigate what 'success' means to each of these stakeholders. For example, an engineering education institution might consider a certain percentage of graduating first class honours students to be an indicator of success and indeed many students may themselves aspire to graduating with first class honours. Obviously not all graduating students will achieve first class honours and many professional engineering careers do not require first class honours. For this reason and to make the study as unbiased as possible, we decided to investigate what the concept of ‘success in engineering education’ means to each of the primary stakeholders and to identify similarities and differences between these perspectives. Therefore, we structure this part of the study as follows:

- Engineering education
    - Success in engineering education
        - Student perspective
        - Engineering education provider perspective
        - Employer perspective

For the Problem Based Learning (PBL) component too we need to consider variations in how PBL is used in different contexts mindful, for example, that what works well in one discipline such as medical education might not produce the same results when applied directly to engineering education. For this reason we structure the PBL component of the study as follows:

- PBL
    - Existing models of PBL
    - PBL in engineering education
    - Characteristics of PBL in engineering education

In section 3 we outline the research methodology and describe the primary instruments which we used to gather the necessary data. In section 4, we establish the theoretical framework for the study. This includes a brief review of the literature relating to our research question and an overview of the popular learning theories, models and assessment methodologies. In section 5 we present, analyse and interpret our empirical data. In section 6 we discuss the findings and draw our conclusions and in section 7 we outline some possible avenues for further work.

3.0 Research Methodology

Beggars can’t be choosers and the multi-faceted nature of engineering education means that the researcher cannot afford to be too selective about what sources of relevant information they will consider. ‘*Ethnographers use many different methods to collect data during their fieldwork. In addition to the field notes which may include records of discussions, chance conversations, interviews, overheard remarks, and observational notes, they may also employ audio and video-recordings and quantitative data gathered from surveys or structured* *observation*' [Case 2014, pg 718]. I have come to believe that anyone wanting to engage in systematic engineering education research must first become an ethnographer in the sense that they must tap into as many sources of data as possible. If it wasn't for a chance conversation with Prof Lars Peter Jensen in November 2011, I probably wouldn't have undertaken this MPBL programme. Indeed, some of my most revealing insights into student success in their engineering education have come from chance conversations with both successful and not so successful students. Of course we can't control the exact time and place of such opportunities to collect valuable data but we can systematically prepare to make the most of them by being constantly on the look-out for them, documenting them in a reflective journal [Schon 1983] and if necessary to follow up with a discourse analysis [Kittleson 2004]. I have tried to take this approach by collecting relevant data from as many useful sources as possible. These sources include student reflective journal submissions, PBL project and process reports, meeting agendas and minutes etc.

If the concept of *success in engineering education* is considered a phenomenon, then a more focused research methodology through which to address our research question can also be viewed as a subtle mix of phenomenography and phenomenology [Case 2014]. Phenomenography takes experience of the phenomenon as its unit of analysis while phenomenology looks for common shared experiences of and attitudes towards the phenomenon.

The research design is also based on an explorative investigation [Olsen 2008 p. 186]. In line with the student-centred priority indicated above, our research methods included an initial student survey (Appendix 1) designed to gain some general insight into student interpretation of success in their engineering education and also to gather some preliminary feedback in relation to what characteristics of PBL they attribute to their success. The initial student survey data was then analysed to inform the design details of the subsequent follow-up focus group session.

Although the main focus of this study centred on student interpretation of success in engineering education, we also considered the views of two other primary stakeholders, namely, engineering education providers and employers of engineering graduates.

3.1 Research Design

Oppenheim (1992 p101) recommends five important aspects of research design which should be considered in test or questionnaire construction, namely,

- *The type of data collection instrument(s) e.g. interviews, questionnaires, analysis of records.* Our data collection instruments include a survey (quantitative and qualitative questionnaire) and a follow-up independently facilitated focus group.
- *The method of approach to respondents e.g. how best to motivate respondents to engage with the instrument*. The survey was emailed to more than 100 students and a total of 53 completed responses were received.

- *The build-up of question sequences*. The initial survey was designed to collect broad quantitative and qualitative data relating to the research question. Based on a preliminary analysis of the survey feedback the follow-up focus group questions were designed to collect further data specifically related to the theme of student attitude to teamwork and how it influenced their individual learning and skills development in their PBL modules.
- *For each specific variable, the order of questions and the possible use of funnelling to capture specific detail*. The follow-up focus group independent facilitator was given guidelines relating to funnelling to capture specific detail (see Appendix 2).
- *The types of question(s) to be used e.g. closed questions with a set of pre-coded answers or free-response open questions*. We used both in the survey. The follow-up focus group was free-response open questions with possible thematic funnelling at the discretion of the independent facilitator.

3.2 Reliability and Validity

Before undertaking quantitative and/or qualitative research it is important to consider two concepts associated with best practice in such research, namely, the reliability and validity of the tests used to gather the research data.

Reliability has two components [Kline 2000], namely, stability over time (also known as test-retest reliability) and internal consistency. A useful benchmark for test-retest reliability is to allow at least three months between the test and retest and then if the correlation between the test and retest is at least 0.8 and the number of subjects in each test is at least 100 then this indicates a good level of test-retest reliability. One obvious limitation of this study was the relatively low number of subjects who completed the initial survey i.e. twenty-four 3rd and 4th year engineering students. A further 29 students with varying levels of PBL experience from engineering-related disciplines also completed the survey bringing the total to 53. However, this is still some way short of the recommended 100 subjects per test to enable a good estimate of the reliability of the data. When PBL was first piloted in the Dept of Electronic Engineering at Maynooth University in 2013 a detailed survey was conducted among the then 2nd year students [Lawlor 2013, 2014]. Those same then 2nd year students have recently graduated and a significant number of them completed the PBL survey designed for this study. Therefore, the relevant data from the 2013 PBL survey was revisited and cross-referenced with the new survey data in order to establish a rough estimate of the test-retest reliability.

The internal consistency of a test is associated with assurance that a test is indeed measuring what it is intended to measure. This can be difficult particularly if the parameter being measured is influenced by more than one variable. To verify internal consistency it is generally recommended to have at least 100 subjects [Kline 2000 pg 12] although Kline also suggests that a reasonable estimate can be computed from sample sizes as low as 10 (pg 13). Again our low number of survey responses makes it difficult to accurately verify the internal consistency of our test. Nonetheless we computed the Cronbach alpha coefficient [Knapp 1991, Peterson 1994] for the survey quantitative data to make a rough estimate of the internal consistency.

The Cronbach alpha coefficient is defined as: $$\alpha = \left(\frac{k}{k-1}\right)\left(1 - \sum \frac{\sigma_i^2}{\sigma_t^2}\right) \quad (3.1)$$

Where k= the number of items, σ_i^2 is the item variance and σ_t^2 is the test variance [Kline 2000 pg 16].

We also applied the split-half reliability test to the same quantitative data. This is a popular simple alternative to the Cronbach alpha coefficient for estimating internal consistency. Kline (2000 p. 13) notes that *'in my experience of actual test construction, split-half reliability and the alpha coefficient have differed only at the third place of decimal, a discrepancy of no practical or theoretical interest'*.

Objective metrics such as the Cronbach alpha coefficient should be interoperated with caution. Van Der Vlueten et al (1991) highlighted a number of pitfalls associated with the *'presumed superiority'* (p. 110) of such objective measures over their subjective counterparts in relation to the reliability of clinical tests.

A test is said to be valid (also known as face valid) if it measures what it claims to measure. Recall that the purpose of this research study is to measure student attitudes, positive and negative. We're not looking to use these attitudes as a predictor of performance but rather as an analysis of experience. Our survey and follow-up focus group asked students to reflect on their experience of PBL (post-action) and how they felt it affected their learning. A test is said to possess concurrent validity if it correlates highly with another test of the same variable administered at the same time. To enhance the concurrent validity of our test, we also examined feedback data from the students' PBL reflective journals and triangulated this with the survey findings. A test is said to possess predictive validity if it gives a good prediction of the criterion being tested. This is important for tests which aim to predict the suitability of prospective engineering students prior to their commencement of their study programme, see for example Immekus (2005) and section 4.1.1 below. Predictive validity is less important in the present study because as noted above we're not looking to use our test as a predictor of performance but rather as an analysis of experience. Incremental and differential validity are associated with two different tests of the same criterion. Ideally two such tests should correlate highly with each other but not too highly. If the correlation is too high then this suggests that the two tests are not unique or are not differentiated from each other. If they are unique then each test contributes new information which is associated with good or high incremental validity. The quantitative and qualitative sections of the survey can be viewed as two different tests of the same criterion. These were analysed separately and compared to make a rough estimate of the incremental validity. Construct validity embraces all of the above types of validity and relates to the level of consistency between the various types of validity for a particular criterion under test. Construct validity can be very strong evidence that a test does indeed measure what it claims to measure. In a follow-up paper to Van Der Vlueten et al (1991), Norman et al (1991) highlighted a number of potential pitfalls associated with objective measures of validity. Nonetheless, serious challenges remain associated with the construct validity of studies which aim to scientifically measure the effect of many active learning interventions [Freeman 2014]. See section 6 for a broader outline of this point.

4.0 Theoretical Framework & Literature Review

Research in educational psychology has shown peer learning to be one of the most powerful forms of learning, drawing upon the 'zone of proximal development' (ZPD), a concept developed by the Soviet psychologist and social constructivist Lev Vygotsky (1896 – 1934) whose work has had a major influence on modern pedagogical theory at many levels.

Kolmos (2006 p.175) cites the work of [Schön 1983] who refers to the importance of reflection in the Aalborg model. Schön states that '*a reflective practitioner is a person who is capable of analyzing situations, choose and use relevant knowledge and reflect on own experiences*.' In this context, Kolmos also refers to reflection as '*another forceful element of learning as advocated by the Kolb cycle of learning*' [Kolb 1984] and further cites the work of another pioneer of modern pedagogical theory, namely John Dewey (1859 - 1952) who has stated that '*we do not learn from experience … we learn from reflecting on experience*'.

Another pioneer of modern pedagogical theory whose work has had a strong influence on the development of the Aalborg model is Jean Piaget (1896 – 1980). Piaget's theory states that '*the key to learning lies in the mutual interaction of the process of accommodation of concepts or schemas to experience in the world and the process of assimilation of events and experiences from the world into existing concepts and schemas*'. [Bruner 1974 p.70] has offered further insight into the practical application of these pedagogical concepts in his '*theory of instruction*' in which he makes the point that the purpose of education is to stimulate inquiry and skill in the process of knowledge getting, not to memorize a body of knowledge: "*knowledge is a process, not a product*" [Bruner 1974, p.72].

[Light 2001] also offers much practical guidance on the application of these pedagogical concepts within higher education contexts. For example, in the context of small group teaching he states that: '*we are now realizing that changing the size of groups can be one of the best ways to encourage independent expression*' [Light 2001, p. 123].

In order to establish a theoretical framework for our research and establish firm terms of reference, we first conducted a brief literature review in line with the conceptual structure shown in section 2 above.

4.1 Literature review

As noted above, the majority of the literature relating to indicators of success in engineering education is based on the engineering educator perspective and/or the employer perspective with very little from the student perspective. In researching the student perspective, our aim is not to ignore the wealth of important findings and recommendations from the educator and employer perspectives but rather to explore their relation to and alignment with the student perspective with a focus on active learning techniques in general and on PBL in particular.

4.1.1 Indicators of success in engineering education - Student Perspective

In 2005, Immekus et al. presented a battery of psychometric instruments (later named as the Student Attitudinal Success Inventory [SASI]) to measure a set of nine non-cognitive attributes of engineering students prior to commencing their first year of study. The nine independent variables (known in this context as constructs) measured by the SASI are intrinsic motivation, academic self-efficacy, expectancy-value, deep learning approach, surface learning approach, problem solving approach, leadership, teamwork skill, and major indecision. Yoon (2014) presents a detailed definition of each of these constructs (see Table 5 of [Yoon 2014]) and also added a further six constructs to the SASI survey and called the new version SASI II. The main purpose of SASI II was to *'assess engineering students' non-cognitive attributes and to use the collected data to predict students' performance in engineering and persistence in the program'* [Yoon 2014 p. 5]. These additional six constructs were goal orientation, implicit beliefs, intent to persist, social climate, self-worth and career decision. Each construct is measured by asking a number of questions to which the student selects their response from a five-point Likert scale (strongly disagree, disagree, neutral, agree, and strongly agree) [Likert 1932]. A related '*main goal*' of Yoon's study was to '*rigorously validate the SASI II, as a tool for assessing engineering students' multi-faceted noncognitive attributes that relate to their college academic performance*' [Yoon 2014 p. 6]. He validates the SASI II tool by computing its construct validity and its internal consistency reliability using data collected from two very substantial cohorts of first-year engineering students, namely, 1,182 responses from 1,700 invitees in 2007 and 1,695 responses from 1,700 invitees in 2008. Its not clear from the paper if the improved response rate from 69.5% in 2007 to 99.7% in 2008 was as a result of any particular intervention on his part. Interestingly, all of the above survey data was collected during the summer before each cohort commenced their first year of engineering study. This highlights an important difference between Yoon's study and the present one in that in the present study we are collecting the student attitudinal data after they have experienced at least two semesters of PBL. A second important difference between the two studies is that while Yoon uses his data to validate the SASI II tool as a predictor of academic performance on the engineering programme, the present study is less concerned with prediction of academic performance and more concerned with the collection and analysis of student attitudinal data relating to their own academic performance and skills development and the role (if any) which their PBL experiences played in their achievement of these learning outcomes. Despite these subtle differences between Yoon's study and the present one, Yoon's methods and findings are nonetheless relevant to our research question. In verifying the construct validity and internal consistency reliability of the SASI II tool, Yoon used factor analysis [Stevens 2002] to identify fifteen independent factors, namely, (a) academic motivation (MTV), (b) persistence (PST), (c) mastery learning goal orientation (MLG), (d) personal achievement goal orientation (PAG), (e) deep learning approach (DLA), (f) surface learning approach (SLA), (g) problem solving approach (PSA), (h) implicit beliefs about intelligence and person as whole (IMB), (i) self-worth in competition (SWC), (j) self-worth in other's approval (SWO), (k) social engagement (SCE), (l) teamwork (TWK), (m) decision making in college major (DMC), (n) fit with major/career (FIT), and (o) occupational confidence (OCC). Yoon computes the Cronbach α coefficient for each of these factors and ranks them in order highest to lowest (see table 4 of Yoon (2014)). The highest is MTV at 0.942 and the lowest OCC at 0.739. Knapp (1991) notes that an α measure of 0.8 or greater is generally accepted as an indication of good internal consistency whereas an α measure of greater than 0.95 is often undesirable as it suggests that the subject responses are insufficiently unique. The fact that all fifteen Cronbach α's are within or close to the Knapp's range suggests good internal consistency for the SASI II test. Knapp's point above suggests, however, that an α measure somewhere in the middle of this range might be more desirable than around its extremities. The factor closest to the middle of the range is MLG (α = 0.878) which Yoon defines as '*Students' orientation to extend their knowledge and understanding for mastery learning with attention focused on the self*' (pg 12). Other factors falling near the middle of the Knapp range include IMB (α = 0.860) defined as the '*students' beliefs about intelligence and person as a whole that are a fixed and nonmalleable entity so that remain the same*'; SLA (α = 0.860) defined as the '*students' surface learning approach consists of thee subconstructs: avoiding novelty (SLAA), memorization (SLAM), and surface strategy (SLAS). Avoiding novelty (SLAA) indicates students' learning approach to avoid unfamiliar or new work. Memorization (SLAM) refers students' preference of learning by rote memorization. Surface strategy (SLAS) indicates students' learning approach with minimal effort to pass the course*'; PST (α = 0.895) defined as the '*students' desire and commitment to finish their engineering program (persistence in engineering, PSTE) and achieve a college degree in the university (persistence in university, PSTU)*'; and PSA (α = 0.899) defined as the '*students' perception of their approach to solve problems in terms of their awareness in the problem solving process and strategies*'; Some of these factor definitions seem open to interpretation such that the significance of three decimal place numerical accuracy in their Cronbach α coefficients is unclear. It would be interesting to apply the split-half reliability test [Kline 2000] to Yoon's SASI II data as a cross-check of his α coefficients[2].

In relation to the above persistence (PST) factor definition the question arises as to the validity of trying to predict with 0.1% accuracy a prospective engineering student's desire and commitment to finish their engineering programme using data collected from them before

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[2] I emailed Yoon to query this point on 11th June 2016 and again on 5th July 2016 but received no reply.

they even start the programme. Surely a more worthwhile undertaking would be to try to identify the learning interventions which if implemented while the student is on the programme would increase their desire and commitment to finish it.

Another issue arises with Yoon's academic motivation (MTV) factor ($\alpha = 0.942$) which he defines as the '*students' overall academic motivation that consists of two subconstructs: intrinsic motivation (MTVI) and academic self-efficacy (MTVS). Intrinsic motivation (MTVI) indicates students' beliefs about their overall confidence in challenging academic work, learning new materials, and working in their chosen profession. Academic self-efficacy (MTVS) refers students' beliefs in future performance to learn engineering basic subject knowledge (mathematics, chemistry, and physics) and academic skills (writing, communication, programming, problem solving, creative thinking, study skills, and teaming skills)*'. The issue here is that the MTVS subconstruct is so broad that it would appear to partially overlap a number of the other factors which it is supposedly independent of. For example, Yoon's teamwork factor (TWK) is defined as the '*students' perception of team dynamics to work as a team in terms of responsibility, respect, and communication*'. Based on these descriptive factor definitions there would appear to be correlated components which would undermine the independence of the factors.

Despite the above face validity concerns relating to Yoon's findings, his sample sizes are very significant, his analysis methods are objectively rigorous and three of the factors which he identifies are directly relevant to the present study, namely

- Self-worth in other's approval (SWO), defined as the student's self-esteem based on other's approval and acceptance.
- Social engagement (SCE), defined as the students' expectation about social engagement with different people in college.
- Teamwork (TWK), defined as the students' perception of team dynamics to work as a team in terms of responsibility, respect, and communication.

Therefore, we deem it prudent to keep his findings in mind as we collect and analyse our own student attitudinal data relating to their perspective on success in engineering education.

Another concern with Yoon's approach is whether the Cronbach α coefficient is indeed the most appropriate metric with which to estimate the reliability of the survey data. Revelle (2009) carried out a mathematical comparison of a number of reliability estimation metrics and found that the so-called ω_t coefficient was superior. He suggests that the reason for the continued widespread use of the Cronbach α coefficient in reliability studies is *'perhaps inertia on the part of editors and reviewers who insist on at least some estimate of reliability and do not know what to recommend'* (p. 153). For this reason we computed both coefficients (α and ω_t) in our quantitative data reliability analysis of our data in section 5.1.1. As mentioned in section 3.2 above, objective metrics such as these should be interpreted with caution in the analysis of subjective data [Van Der Vlueten et al 1991], [Norman et al 1991], [Peterson 1994].

Although, we had little control over our sample size we were concerned that it might not be large enough to ensure sufficient test reliability and internal consistency. Bonett (2002) notes that recommended sample sizes vary significantly from 15-20 according to Fleiss (1986) to 300 or more according to Nunnally and Bernstein (1994). Bonett also presents a number of formulae *'to determine the sample size needed to test coefficient alpha with desired power or to estimate coefficient alpha with desired precision'* (p. 335).

As noted above, it's difficult to find primary data on student perspective on success in engineering education mainly because students simply don't publish in numbers. However, Yeeles and McGregor (2014, 2016) recently published a guideline document containing what they describe as '*new insights into what students are looking for*'. The source of data upon which they developed these new insights was a student innovation competition which was hosted by the UK-based Joint Information Systems Committee (JISC) in 2013. Twenty one student project proposals were funded and McGregor notes that a '*side benefit*' of the competition was '*an amazing amount of intelligence about what students want*' (p. 1). Thirty seven student teams entered the competition by submitting a video about their innovative idea. There were 13,095 video views of these proposal videos and 6,475 student votes for the initial proposals. 21% of voters left supporting comments as well as voting. Based on the outcome of the voting, students' interest areas submitted for the competition were divided into four areas, namely, teaching and learning, research, student life and improving organisational infrastructure. '*By far the majority of the student proposals were aimed at improving their learning experience*' (p. 3). One such project (studentVLE.com) attracted a lot of interest among voters with many commenting on its '*networking on a national scale and peer learning*' (p. 3) features. Yeeles notes that '*60% of the 333 votes for this popular project came from people outside the project team's own university*' (p. 3). Based on their analysis of the competition data Yeeles and McGregor presented a number of factors which they believe to be '*instrumental in successful student engagement*', including[3],

- *Finding a <u>balance between supporting students and intentionally leading them</u>, which could crush their innovation.*
- *Finding ways to <u>mix students with different skill sets</u> is important for robust ideas.*
- *<u>Non-technical</u> project leads can be matched up with staff or students with those skills. For example, the social anthropology <u>undergraduate</u> who created PitchPatch [/research/projects/pitchpatch] <u>teamed up with a group of more technical students</u>.*
- *Supporting students to <u>investigate their ideas before activating them</u>. For example, there may be existing commercial alternatives that students may not be aware of. A staff mentor can help with this.*

[3] Note that some text has been underlined to highlight specific points related to this study.

- *Showcasing the benefits of student innovation – they'll gain coding, project management experience and other skills that are highly relevant to their future employability, a big driver for student engagement.*
- *Students often need help with appreciation of timescales and process. What they might not realise is that by the time they've finished creating their solution, the students themselves may have finished their course.*
- *Students can be critical of the status quo. Often, engaging students in the process of finding solutions helps them understand the complexity and issues especially when they get down to implementation.*

An interesting feature of the above factors in student success based on student generated data is the alignment of many of the concepts implicitly noted with features of best practice in student-centred learning and problem based learning. For example, concepts such as those which we have underlined in the above factors feature prominently in our review of student-centred learning and problem based learning in section 4.1.2 below as well as in [Prince 2004 and Chickering 1987].

In 2013 the Higher Education Authority (HEA) in Ireland conducted a pilot survey of student engagement [ISSE 2016]. Since the 2013 pilot, the Irish Survey of Student Engagement (ISSE) has become established as an annual national initiative. In 2015 more than 27,300 students from thirty higher education institutions completed the survey. '*The survey collects information on how students engage with their learning environments. Students' engagement with college life is important in enabling them to develop key capabilities such as critical thinking, problem-solving, writing skills, team work and communication skills*' (ISSE 2015a p. 3). The institutions have full access to the survey data which they can analyse, for example, to try to identify common themes in terms of what they do well in engaging students in learning and what they could do better. For example, Trinity College Dublin analysed the survey data from their students and '*found that results were highly consistent for first years across all faculties. It was found that improvements identified related to students requesting 'more of' what they regarded as good aspects e.g. active, independent and problem – based learning, group learning or group projects, small classes/tutorials, continuous assessment and engagement/ interaction with staff*' (ISSE 2015b p. 25). The survey only collects feedback from first year, final year and postgraduate students so that the above '*more of*' summary feedback comment is based on data from students with just over one semester of higher education in one (albeit large) institution. It would be interesting to analyse the corresponding final year student feedback to see if the same sentiment prevailed.

Prince (2004) carried out a review of active learning approaches and notes that '*studies suggest that PBL develops more positive student attitudes*' (p. 7), however, he also notes that active learning in general is '*a topic that frequently polarizes faculty*' (p. 1). He presents a very balanced overview of the arguments and evidence for and against active learning including PBL which we summarize in more detail in sections 4.3-5 below.

4.1.2 Indicators of success in engineering education (engineering educator perspective)

Arguably the majority of the literature relating to success in engineering education comes from engineering educators [Aditya 2014]. Much of this literature gives some level of consideration to the various stakeholders involved such as students and employers. However, most higher education institutions develop and periodically review their strategic plan [MU 2012] which sets out mission statements, long term and short term goals and associated target objectives along with indicators of success on the achievement of such objectives. Higher education schools and departments are encouraged to take a similarly strategic approach and to align their strategic plan with that of the institution. Such joined up thinking is good but it doesn't necessarily imply equal representation of all stakeholders and the priorities of the educator often take precedence over those of the students for example. Strategic priorities from the educator perspective typically include a range of interrelated issues such as attracting the best students in the right numbers, student retention, time to completion, professional accreditation of education programmes, research funding and publications, etc. With so many priorities competing for the attention of the educator, the learning experience of the student often gets pushed down the priority list. Much too is written about so-called 'student-centred' learning which the Glossary of Education Reform [http://edglossary.org/] defines as '*a wide variety of educational programs, learning experiences, instructional approaches, and academic-support strategies that are intended to address the distinct learning needs, interests, aspirations, or cultural backgrounds of individual students and groups of students*'. Few will argue against the value of such a concept but with so many factors to contend with, identifying exactly how best to move towards a more 'student-centred' learning environment is not at all obvious. Indeed, the same glossary further states that '*it may be difficult to determine precisely what the term is referring to when it is used without qualification, specific examples, or additional explanation*'.

Chickering and Gamson (1987) presented seven principles of good practice in higher education which have gained widespread acceptance among the higher education community. These seven principles are summarized as follows:

Good practice in undergraduate education:

1. Encourages student-faculty contact.
2. Encourages cooperation among students.
3. Encourages active learning.
4. Gives prompt feedback.
5. Emphasizes time on task.
6. Communicates high expectations.
7. Respects diverse talents and ways of learning.

These principles look great in theory but many faculty will legitimately ask if they are practical. For example, if I have 300 students and a lot of material to get through then this might leave very little time for student-faculty contact. Many faculty will say that they'd love to do more active learning if only they had more time and/or resources. Such comments from the higher education community do indeed highlight some serious challenges associated with working to these seven principles. However, there is evidence that active learning approaches need not be more demanding of faculty time than many traditional programme delivery methods. For example, in a recent thorough review of PBL and teaching behaviour, Hoidn (2014 p. 8) notes that '*People learn – understand – best when they can discover and construct knowledge for themselves in an unguided or minimally guided environment (e.g. Bruner, 1961; Duckworth, 2006)'.* In fact, Hoidn goes further to state that '*In general, student-centred approaches such as discovery learning, problem-based learning, inquiry learning, experiential learning and constructivist learning account for such minimal direct guidance*' [OECD 2014 p. 8]. Our own research concurs with this finding. For example, in 2013 we piloted a 10 ECTS credit PBL pilot module in our electronic engineering programme and to our surprise, the pilot proved significantly less (approx 50%) demanding of staff time than the workload associated with 10 ECTS credits worth of conventional module delivery [Lawlor 2014].

There are growing numbers of examples emerging in the literature of practical learning interventions which align well with the Chickering and Gamson principles and result in a more student-centred learning environment [Cowan 2004, Freeman 2014]. Graaff & Kolmos (2003) looked in detail at a number of universities at which PBL has been used extensively for many years and identified three common characteristics of the PBL models in use at these universities, namely, the programme or curriculum structure, the learning process and the assessment. More detail on these characteristics is presented in section 4.3 below.

Freeman et. al. (2014) too conducted a comprehensive meta-analysis of 225 studies of active learning versus traditional lecturing in science, technology, engineering and maths (STEM) and found that the active learning approach reduced failure rates and boosted scores on exams by almost one-half a standard deviation. Freeman also raises an important question relating to the construct validity of these studies which we discuss further in section 6.

4.1.3 Indicators of success in engineering education (employer perspective)

In an OECD review of workforce skills for innovation, Toner (2011) states that '*it is generally argued that the increased rate of innovation across economies requires the workforce to possess both technical competence and what are termed 'generic skills' - problem solving, creativity, team work and communication skills*' (p. 8). Prince (2004) notes that '*employers frequently identify team skills as a critical gap in the preparation of engineering students*' (p. 5). Engineering education programme accreditation bodies are explicit about the key skills which they look for among graduates. For example, the US Accreditation Board for Engineering and Technology (ABET) states that upon graduation an engineering graduate is expected to have [ABET 2016 p. 3]:

- *a. an ability to apply knowledge of mathematics, science, and engineering*
- *b. an ability to design and conduct experiments, as well as to analyze and interpret data*

c. *an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability*
d. *an ability to function on multidisciplinary teams*
e. *an ability to identify, formulate, and solve engineering problems*
f. *an understanding of professional and ethical responsibility*
g. *an ability to communicate effectively*
h. *the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context*
i. *a recognition of the need for, and an ability to engage in life-long learning*
j. *a knowledge of contemporary issues*
k. *an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.*

A further challenge for the engineering education community is that workplace skills required of engineers are continuously changing in response to the ever-changing needs of society. In fact, ABET (2016_ch) note that the above list of so-called student outcomes was '*written 20 years ago in preparation for outcomes-based education*' (p. 25). They also note that '*graduates of programs accredited by the EAC must be prepared for professional practice of engineering, and engineering is evolving to meet continually emerging demands*' and are currently engaged in a revision of these student outcomes and associated curriculum criteria. The currently proposed revised set of student outcomes being considered by ABET are [ABET 2016_ch]:

1. *An ability to identify, formulate, and solve engineering problems by applying principles of engineering, science, and mathematics.*
2. *An ability to apply both analysis and synthesis in the engineering design process, resulting in designs that meet desired needs.*
3. *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.*
4. *An ability to communicate effectively with a range of audiences.*
5. *An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.*
6. *An ability to recognize the ongoing need for additional knowledge and locate, evaluate, integrate, and apply this knowledge appropriately.*
7. *An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.*

It's very encouraging to see student outcome 7 relating to teams and specifically spelling out a number of process competencies central to group PBL. Although the current proposed revised curriculum criteria states that '*the curriculum must support attainment of the student* *outcomes*', it doesn't specify explicit criteria aimed at supporting student outcome 7. The author brought this apparent potential short-coming to the attention of the ABET board of delegates (See appendix 5 below) under the terms of the on-going consultation process.

Many of the above abilities and draft student outcomes are best developed experientially [Prince 2004, Freeman 2014]. Many engineering faculty will ask how is it possible to cover the necessary technical syllabus and at the same time provide opportunities for students to develop the above skills and abilities experientially. In 2004, Kjærsdam presented findings of a comparative study carried out by independent consultants, Instituttet for Opinionsanalyse (IFO), in cooperation with the Danish magazine Ingenioren in which the directors of human resource management at 487 companies which employed graduates of two universities were surveyed. The key findings of this survey are presented in Figure 4.1.

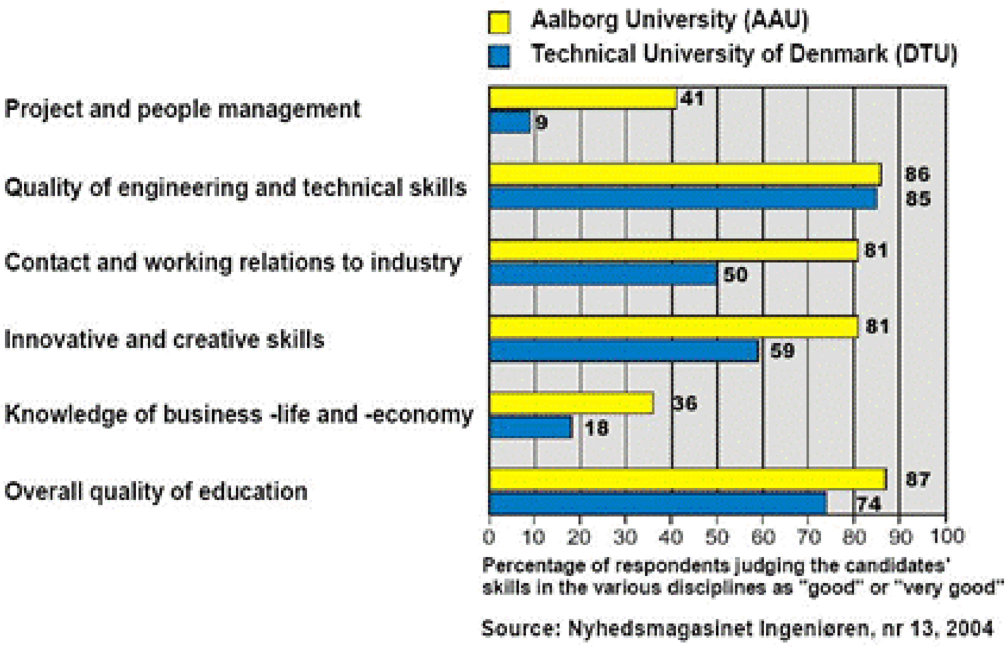

Figure 4.1. PBL vs non-PBL comparative study [IFO 2004] [Kjærsdam 2004]

Kjærsdam notes that '*Denmark is, in many ways, a laboratory where PBL's success can be verified*' (p. 65). The two universities cited in the comparative study are the two main technical universities in Denmark and were similar in many respects over the 30 years prior to the study. However, they differed in one important respect, namely, their '*modes of education*' with Aalborg University (AAU) educating engineers '*based on problem-based project work*' while the Technical University of Denmark (DTU), Copenhagen, '*educated engineers in a more traditional manner using lectures that have been supported by laboratory work and projects*' [p. 65]. The sheer scope and longevity of this comparative study should not be underestimated and the significantly superior performance of the PBL graduates behoves all engineering education stakeholders to carefully consider the integration of PBL into their programmes. In the next section we present a brief review of PBL with a particular focus on its use in engineering education.

4.2 Problem Based Learning

Modern PBL practice has much in common with the so-called *project method* which is generally associated with Kilpatrick [Kilpatrick 1918]. The systematic use of project work in educational programmes can actually be traced back over several hundred years. Knoll [Knoll 1997] has identified five distinct phases in the history of the project method. These phases are:

1590 – 1765: The beginning of project work at architectural schools in Europe.

1765 – 1880: The project was used as a regular teaching method and was transplanted from Europe to America as well as beginning to find application in Engineering education. Two schools of thought emerged, namely, those who argued that *'theory and practice belonged together'* and saw the project method as an effective means to facilitate this and those who argued that *'the scientific engineer was the ideal'* (see [Knoll 1997 p. 61]).

1880 – 1915: The use of projects was adopted in manual training and in general public schools, [Woodward, 1887].

1915 – 1965: Redefinition of the project method and its transplantation from America back to Europe. A reactionary movement to what Woodward termed 'a new departure' emerged based on the argument that over-emphasis on 'hand' or practical education would stifle the creativity of the student. One of the pioneers of this movement was John Dewey (1859 – 1952), an American philosopher whose ideas had a strong influence on the development of both problem and project-based learning. A central facet of Dewey's educational philosophy was the need to strike the right balance between knowledge-delivery and hands-on or experiential learning through active enquiry. Another pioneer of this period was William H. Kilpatrick (1871 – 1965), an American pedagogue who was strongly influenced by Dewey's ideas on education. Kilpatrick's 1918 publication titled *'The Project Method: The Use of the Purposeful Act in the Educative Process'* led to his name being widely associated with the modern project method.

1965 – present: Rediscovery of the project idea and the third wave of its international dissemination. The 1960's saw a significant growth in demand for higher education in the more industrialized nations. This in turn resulted in a growth in interest the effective delivery of quality higher education programmes [Graaff & Kolmos 2007]. It was against this backdrop that interest emerged in the adaptation of project and problem-based learning for use in higher education. Much of the early development in this regard is associated with medical education (see section 4.4 below) although interest quickly spread to other areas such as engineering and science as academics and employers began to recognize the potential of these techniques.

4.2.1 Summary

One source of confusion in the PBL literature is whether the PBL acronym stands for *problem based learning* or *project based learning*. In the modern PBL literature, these two albeit closely related concepts do in fact have a number of characteristics which make them different. Savin-Baden (2003) presents a summary of these distinguishing characteristics which we reproduce in Table 4.2 below.

Graaff (2012 slide 19) also states that '*project based learning is more often seen as a teaching technique in a given area of the curriculum rather than an overall educational strategy such as problem based learning'*.

Problem-based learning	Project-based learning
Process	Product and outcome
Focus on the problem	Focus on problem solving
Students work out learning needs	Lectures
Facilitation	Supervision
Can be from the beginning	Often in the end of the degree
Learning cross disciplines is a necessity	Can bring together taught subjects

Table 4.2 - Differences between problem-based and project-based learning according to Savin-Baden (2003)

It seems that striking the right balance between the co-education of the brain (exclusively intellectual) and the hand (practical), as Woodward puts it, has remained a bone of contention in educational philosophy right up to the present day. Perhaps there is no right balance or at least the right balance is so context-dependent that what works well for one age-group on a particular education programme will not necessarily work when applied to a different age-group and/or programme. The demands of many modern industries and professions often change such that a purely practical graduate skill-set is likely to become quickly obsolete in this age of 'life-long learning'. Woodward's description of the educational trade-off between exclusively intellectual and practical education may be less applicable to many areas of modern education with the growing demand for practical skills such as communication and teamwork skills which have very little to do with the 'hand'. Such so-called 'soft-skills' are widely recognized as important drivers of collaborative innovation which many modern companies and corporations rely on in order to remain competitive [Katzenbach, 2006].

Many higher education institutions recognize the importance of such skills but struggle to effectively integrate their development into their programmes. There is, however, growing evidence that the key to successfully integrating the development of such skills into existing curricula is not to bolt on yet another course(s) but rather to recognize that such skills are best developed experientially and to adapt the programme structure and delivery to facilitate such experiential learning [Moesby 2005, Kolmos 2014]. Such programme structures and delivery techniques have received significant and growing interest in recent years and comprehensive comparative studies have indicated that graduates of such programmes show significant advantages over their conventional counterparts [IFO 2004, Kjærsdam 2004]. In the following sections we present an overview of the key characteristics of these programme structures and delivery techniques.

4.3 PBL Models

In [Barrows 1996], problem-based learning is defined as having three central attributes, namely,

- student-centred
- involving small groups of students working as a team with an academic facilitator offering advice in a 'guide-on-the-side' capacity but not getting involved at the work level and
- each group project is organized around a specific problem.

These three central attributes help clarify the close relationship between problem-based learning (PBL) and project-based learning (also PBL!) which, as discussed in the previous section, are often used interchangeable and confusingly to refer to variations on the PBL theme which are often non-compliant with the above Barrows attributes. For example, a student working individually on a final-year project is not compliant with the Barrows definition of problem-based learning. The missing attribute in this context is the structured facilitation of peer-learning which is necessary for the effective development of important skills such as communication and teamwork skills.

Savin-Baden (2003) has identified five variations of the above PBL model with each variation being based on a slightly different pedagogical objective:

- PBL for attainment of knowledge
- PBL for professional work
- PBL for interdisciplinary comprehension
- PBL for cross-discipline learning
- PBL for critical competence.

Despite the wide variation in PBL models, [Graff and Kolmos 2003] have identified seven pedagogical principles which are common to these PBL model variations, namely,

- Problem-based i.e. the starting point of the learning process is the consideration of a problem, preferably a real problem as this can be more motivating to the students than an artificial problem.
- Participant-directed or self-directed i.e. the students are given freedom to orient and formulate the problem specification as well as directing the development of a solution.
- Experiential learning i.e. the students are required to build on their previous experience and interests.

- Activity-based i.e. the students are actively engaged in research, decision-making, writing etc.
- Interdisciplinary i.e. the solution to the problem will and should typically span traditional subject boundaries.
- Exemplary practice i.e. whereby depending on the nature of the particular problem, students may not be guaranteed to achieve all of the documented learning outcomes associated with a particular subject module. This short-coming, however, is offset by the fact that the students are instead ‘learning-to-learn’ and as such will be better equipped in the future to ‘fill in’ subject-specific content gaps.
- Group-based i.e. peer-learning is facilitated and encouraged as this is also central to the effective development of communication and teamwork skills.

As noted above, Graaff and Kolmos (2003) also looked in detail at a number of universities at which PBL has been used extensively for many years. These universities included Maastrict University in Holland, Linkoping University in Sweden, McMaster University in Ontario, Canada and Newcastle University in Australia. They also considered the PBL-related practices at their own university, namely Aalborg University in Denmark which, since its foundation in 1974, has developed a worldwide reputation as a centre of excellence in project- and problem-based learning. Based on their analysis of the PBL-related practices at Aalborg and the other universities listed above, which are also recognized centres of excellence in PBL, they identified certain common characteristics of the PBL models in use at these universities. These common characteristics are:

- Programme or Curriculum Structure

Each study programme is structured into a logical series of thematic semesters. In this way, all of the taught modules delivered in a particular semester are directly related to the semester theme. The student project topics within any particular semester are also directly related to the semester theme and provide a structured mechanism for each project group to discuss, reflect on and apply the taught module content in specifying, orienting, analyzing and ultimately solving the problem upon which their group project is based. Such a structure aligns well with principles 2, 3 and 5 above. Kjersdam (1994) presents detailed guidelines on how to organise the curriculum into themes in an engineering programme (p. 16).

- The Learning Process

Students work in groups which aligns directly with principle 2. Each group has a facilitator with whom they typically meet once per week which enables compliance with principles 1, 4 and 6. Just because the PBL learning process enables compliance with these principles doesn’t imply that it guarantees it. A common criticism of PBL from students is that they are given a problem at the outset and after that their facilitator is too busy to meet them. If the above programme structure is in place then an experienced facilitator can play a very important part in the learning process. This does not mean that the facilitator spends lots of time with their group(s). In fact, Kolmos (2014) states that '*a good PBL facilitator does just two things, namely, they observe and they comment*'. The terms of engagement of the group meetings and the group-facilitator meetings are central to aligning the learning process with principles 1, 4 and 6. Jensen (2013) notes that '*groups who take the time to agree and work to a collaborative agreement tend to do better*'. Group sizes vary across different universities as well as across semesters within individual university programmes.

- Assessment

'Assessment drives learning' and close alignment of the assessment methodologies with the programme learning objectives is another characteristic of best practice PBL models. Graaff and Kolmos (2003) cite the absence of such alignment as *'one of the classic mistakes made when changing to PBL'* [p. 659]. If important process competences are to be effectively achieved, then this importance needs to be reflected in the assessment methodology. Fundamental to this alignment of assessment methodology with programme learning outcomes is the percentage allocation of marks to the programme components. At Aalborg University project work accounts for 50% of the students' time and this percentage is also allocated to the project assessment [Moesby 2004]. Studies show that this percentage is optimal in the sense of allowing students sufficient time to actively reflect on the application of the taught material in a real problem-solving scenario [Moesby 2002, Kjersdam 1994].

Despite these findings, Graaff notes that many universities only allocate around 20% of the student time and marks to project work. This relatively low percentage effectively devalues the importance of process competence development in favour of an *'overstuffed curriculum'* [Graaff 2003 – p. 661] and significantly reduces the opportunity for students to actively engage in the application of taught content to the project(s) with which it is supposedly associated. This in turn can often result in a 'bolt-on' PBL component rather than a properly integrated PBL programme. As noted in [Barrows 1996], such bolt-on PBL variations are relatively common and generally result *'as a compromise with faculty unconvinced about the value of PBL'* (p. 4). Not surprisingly such bolt-on PBL programmes are highly unlikely to realize the full value of PBL but an even greater concern is the fact that their failure to realize the full value of PBL is then cited by the same unconvinced faculty as a reason to revert to a traditional teacher-centred sage-on-the-stage model. This point relates directly to Chickering and Gamson principle 5 above in the sense that if we want our undergraduate engineering students to develop important skills such as teamwork, project management and communication skills this needs to be aligned with the time and marks allocation to the tasks associated with the development of these skills. By giving the students the opportunity to self-direct their own learning, albeit within the thematic semester structure described above and with appropriate guidance from the facilitator, the model also aligns well with Chickering and Gamson principle 7. Cowan (2004) used peer-assessment to help engineering students to develop their self-assessment capabilities and then he further integrated this capability into the learning activities. Such an approach also aligns well with Chickering and Gamson principles 2 and 3 but more importantly it encourages the students to reflect on their learning activities and on their level of achievement of the associated learning outcomes. This in turn resonates strongly with John Dewey's famous quotation: *'we don't learn from experience, we learn from reflecting on experience'*.

4.4 PBL in Medical Education

The majority of the modern PBL literature comes from the medical education community. This dates back to the late 1960's when the McMaster university in Hamilton, Ontario, Canada established a new medical school within its faculty of health sciences [Spaulding 1969]. Motivated by the then *'current dissatisfaction with medical education'* (p. 659), Spaulding and his colleagues set about *'experimenting with novel approaches'* to medical education [Spaulding 1991]. This pedagogical event was a key milestone in the development of modern project and problem-based learning (PBL) and marked the beginning of a trend which has since grown steadily in medical education throughout the world as well as finding extensive application in other disciplines such as law, science, engineering and business [Boud 1991]. In justifying his move to a PBL approach, another pioneer namely Howard Barrows noted that *'studies of clinical reasoning of students and resident physicians in neurology suggested that the conventional methods of teaching probably inhibit, if not destroy, any clinical reasoning ability'* [Barrows 1972 p. 274]. Other universities where PBL was introduced into medical education programmes during the early 1970's included Michigan State University [Jones 1984], Maastricht University in the Netherlands and Newcastle University in Australia. During the 1980's the spread of PBL in medical education continued. A significant milestone in the widespread acceptance of PBL among many of the more traditional medical schools was the so-called GPEP report (General Professional Education of the Physician) published in 1984 by the Association of American Medical Colleges [Muller 1984] which recommended the use of PBL in medical education. By the 1990's *'countless medical schools in the US'* had developed or were in the process of developing PBL curricula [Barrows 1996].

As the number of medical schools introducing PBL into their curricula grew, so too did the number of variations of the PBL educational model grow. Such variations are encouraged provided they adhere to recommended best practice in making a change towards PBL [Moesby 2004]. A common weakness of some such variations is that they may include blending PBL with elements of conventional teaching into a hybrid *'as a compromise with faculty unconvinced about the value of PBL'* [Barrows 1996 p. 4]. Barrows emphasizes the importance of this point under the heading of an *'Integrated Knowledge Base'*, stating that: *'All medical school disciplines basic to medical practice need to be incorporated into the problem-based learning curriculum. In a number of schools, some disciplines are taught outside the PBL curriculum. Not only does this inhibit integration of those subjects in the student's understanding of a patient's problem, it also requires students to move in and out of different learning approaches, passive versus active, dependent versus independent'*. Barrows' point highlights the need to integrate PBL into an education programme in a coordinated manner rather than ‘bolting on’ one or two PBL modules and expecting to see the full benefit of PBL.

4.5 PBL in Engineering Education

Engineering as a profession became established around the late 18^{th} century and through its close association with architecture, engineering education began to inherit some of the project work practices which were well established in the architectural schools in Europe at that time [Knoll 1991]. Despite such early developments, it wasn’t until the early 1970’s that the systematic integration of PBL into engineering curricula began in earnest. Following the pioneering work by Spaulding, Barrows and their colleagues at the McMaster medical school on the use of PBL in medical education, Donald Woods in the Faculty of Engineering also at McMaster began to develop PBL approaches to engineering education [Woods 1994, 2000]. Around the same time that Woods and his colleagues were exploring the use of PBL in engineering education, interest in *‘project pedagogy in engineering education’* began to emerge in Denmark. Such interest was marked by the establishment of two new universities, namely, Roskilde university in 1972 and Aalborg university in 1974 [Graaff & Kolmos 2007]. Aalborg university was established as a ‘developmental’ university with a primary objective being *‘to help solve development problems in the underdeveloped regional society through problem oriented research and teaching’* [Kjersdam 1994].

Traditional engineering education is closely connected with the understanding of scientific and technological development [Kolmos 2006]. Kolmos further argues that while this scientific-technological component is very important, it needs to be complemented with a socio-cultural component. The systematic integration of such a complementary socio-cultural component into engineering education is a central element of the Aalborg PBL model. Kolmos refers to the learning outcomes of the socio-cultural (or group project oriented) component as process skills or competences and states that ‘*there is a growing awareness that learning methods can be used as a means to achieve process skills, and that engineering education as a whole has to change from a very teacher-centred to a more student-centred system*’ (p. 183). Another significant feature of the Aalborg model is that it systematically engenders peer-learning among project-group members.

[Woods 2000] also offers a wealth of practical guidelines relating to tried and tested instructional methods aimed at the integration of process skills development into engineering educational programmes.

In [Moesby 2002], he notes that in year 1 of the Aalborg engineering and science programme, the focus is more on the fundamentals of engineering and science as well as the fundamental process skills. In this context he states that at Aalborg University, *‘during the first year of studies, students learn to adapt to Problem-Based Learning (PBL), along with the acquisition of necessary basic knowledge within fields of mathematics, physics, information technology, and discover the relationships between technology, as well as the context in which the technology appears’* (p. 145).

[Moesby 2004] also offers detailed guidelines relating to making the transition from a conventional lecture-based delivery of an engineering education programme to one based on the Aalborg model. In this paper, Moesby stresses the importance of adapting the core principles of the Aalborg model to the local context rather than trying to replicate them in detail. For this reason he suggests that the most effective way to make such a transition is to phase it in over the duration of the education programme i.e. for a four-year engineering programme, the transition should be phased over four years, beginning with a new cohort of incoming first-year students. Such a phased approach allows time to reflect on experience and refine accordingly in adapting the model to the local context. He also presents useful guidelines relating to the recommended administrative and institutional supports needed for the most effective transition to an Aalborg-styled model.

[Kolmos 2008] also presents a comprehensive overview of the Aalborg model including a detailed description and comparison of the various styles of group project facilitation in a PBL environment.

4.5.1 PBL at Maynooth University

The majority of the students who took part in the study were in years 3 and 4 of the Electronic Engineering programme at Maynooth University. PBL was first introduced into the Electronic Engineering programme at Maynooth University on a pilot basis during year 1, semester 2 of the 2012/13 academic year. This pilot module was based on the Aalborg PBL educational model but was adapted to take account of local contextual differences such as student demographics and prior experience of group project work. The pilot module was integrated into the second semester of the four-year engineering programme such that the project theme was closely associated with previous and parallel taught module content while still allowing significant scope for student direction/ownership. The project module comprised one third of the total student workload i.e. 10 out of 30 ECTS credits which equated to a nominal total of 250 hours project work per student over the semester. Further details of the original pilot study are presented in [Lawlor 2014] and the PBL module descriptor is shown in Appendix 4. Following the successful pilot, a similar PBL module was introduced into year two of the programme. The module descriptor for the current year 2 PBL module is also shown in Appendix 4.

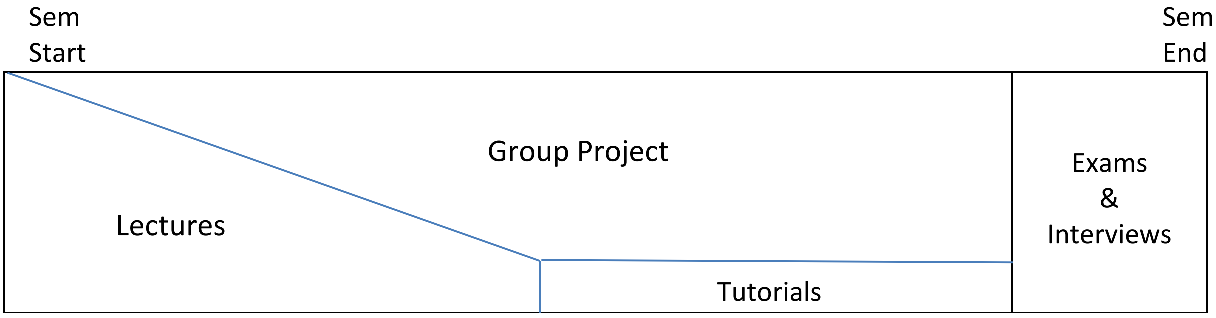

Figure 4.2 - PBL Module Delivery

For more detail on the above PBL model, see section 2.3 of the Teaching Portfolio.

Two further core modules in years 3 and 4 of the programme have also since been adapted for a PBL delivery. These modules are EE301 (Signals & Systems) and EE401 (Digital Signal Processing). The module descriptors for these modules are also shown in Appendix 4. Figure 4.2 gives an overview of these two PBL modules which are also based on the Aalborg model although they are each only 5 ECTS credit modules.

5.0 Empirical findings:

5.1 Data Collection and Preliminary Analysis

The instruments used for data collection were an initial short questionnaire associated with the research question (see Appendix 1) followed up by an independently facilitated focus group with a group of five 3rd and 4th year engineering students who had completed the questionnaire. The preliminary feedback from the questionnaire (first 24 responses) was analysed and used to design the follow-up focus group questions and funnelling guidelines for the independent facilitator (see Appendix 1).

	Not so Important 1	2	3	4	Very Important 5
Graduating with first class honours	3/53	3/53	10/53	20/53	16/53
Graduating with at least a 2.1 honours	1/53	0/53	5/53	15/53	30/53
Just passing my exams and graduating	16/53	11/53	10/53	2/53	11/53
Developing my teamwork skills	0/53	1/53	2/53	26/53	22/53
Developing my presentation skills	0/53	0/53	8/53	21/53	21/53
Developing my report writing skills	0/53	1/53	7/53	24/53	21/53
Developing my project management skills	0/53	0/53	6/53	18/53	29/53
Being able to apply my theoretical knowledge to solve real-world problems	0/53	0/53	2/53	6/53	45/53

Table 5.1 – Collated Quantitative Questionnaire Feedback

A total of 53 survey responses were collected. Forty-one of these responses came from Engineering students who had successfully completed at least two substantial PBL modules prior to the study. The remaining responses came from students from other disciplines who had completed just one substantial PBL modules prior to the study. Table 5.1 shows the collated quantitative feedback for the entire set of 53 responses. Appendix 1 also contains the collated responses for the various sub-groups.

The first three questions relate to the hopes or aspirations of the students regarding their final degree classification. The fact that 16 out of 53 (30%) rate '*Graduating with first class honours*' as very important suggests that this 30% may be hoping to achieve this grade although in reality the percentage of students who actually achieve this grade is significantly lower for our BE programme at around 8% for the engineering programme which the majority of the respondents are taking (between 2012 and 2015 inclusive, 8 out of 86 graduates achieved first class honours on the BE programme). One possible explanation for this apparent inconsistency is that the strategic mind set of many of these students is to 'aim high' so that even if they fall short of their ideal target grade they'll still be content with their result. It's interesting that almost double the above number i.e. 30 out of 53 (57%) rate '*Graduating with at least a 2.1 honours*' as very important. In hindsight, it's a rather vague question in that it essentially covers two grades i.e. 2.1 honours and first class honours. One interpretation is that this 57% includes those who are strategically aiming for a 2.1 honours knowing that realistically it might be beyond their reach but it's still worth their while aiming for it. This interpretation is consistent with the fact that the actual number of 2.1 grades (60 – 69%) for the engineering programme is around 37% (between 2012 and 2015 inclusive, 32 out of 86 graduates achieved a 2.1 grade on the BE programme). The third question generated an interestingly bimodal set of responses. The fact that 11 out of 53 (21%) rate '*Just passing my exams and graduating*' as very important is reasonably reflective of the numbers who might typically struggle to pass their exams. A reassuring feature of the feedback data on these first three questions relating to grades is the relative consistency of the responses with a typical bell-shaped distribution of grades for most engineering (or other) programmes. This consistency gives some level of confidence that the remaining responses are a genuine representation of the student attitudes and further that the cohort of responders is representative of the full range of abilities typically seen in a graduating class.

5.1.1 Quantitative Data Reliability Analysis

In order to estimate the reliability of our quantitative survey feedback data we computed the Cronbach alpha coefficient [Knapp 1991] for both the preliminary (first 24 responses) data as well as the entire set of 53 responses. We used a 14-day free trial version of the IBM SPSS Statistics (version 24) Software Package [IBM 2016] to compute the Cronbach alpha coefficients. We also used the open-source R programming language [R 2016] to verify our Cronbach alpha coefficients and to carry out some other recommended reliability estimation tests such as the split-half reliability test and the ω_t coefficient which according to Revelle (2009) gives a better indication of reliability than the Cronbach alpha coefficient. Appendix 3 shows the detailed statistical analysis from both the IBM SPSS and the R software packages. Table 5.2 shows a summary of the Cronbach alpha and ω_t coefficients computed.

As seen in Table 5.2, in some cases the tests produced negative Cronbach alpha coefficients. In such cases the test report included a warning such as:

'The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings'. See, for example, Test 16 in Appendix 3.

Also, as seen in the table, the tests produce two versions of the Cronbach alpha coefficient, namely, α and α_s. According to the IBM SPSS support documentation [IBM 2016], the first Cronbach's alpha (α) employs the covariances among the items, whereas the second one (α_s) which is based on standardized items employs the correlations among items. The latter alpha is based on the assumption that all of the items have equal variances, which is often false in practice.

Test Number	Input Data	Software Platform	α	α_s	Split-Half		ω_t
1	First 24 responses: all 8 items	SPSS	.370	.480			
2					-.446	.749	
7, 8		R	0.66	0.71			0.82
3	First 24 responses: items 4 to 8	SPSS	.794	.772			
4					.877	.351	
9		R	.79	.77			.91
5	First 24 responses: items 1 to 3	SPSS	-.410	-.223			
6					.344	-ve	
10		R	0.4	0.44			.51
11	All responses, all 8 items	SPSS	.414	.548			
12					-.149	.675	
17		R	0.41	0.55			0.8
13	All responses: items 4 to 8	SPSS	.744	.722			
14					.811	.383	
19		R	0.74	0.72			0.79
15	All responses: items 1 to 3	SPSS	-.113	.068			
16					.673	-ve	
20		R	0.53	0.59			0.79

Table 5.2 – Summary of Reliability Statistical Analysis (see Appendix 3)

We also split the 8 items in question 1 into two groups, namely, items 1 to 3 and items 4 to 8 respectively. The reason for this grouping of items was that we felt that each of these two sub-groups of items were naturally associated with separate constructs i.e. items 1 to 3 with what we might describe as 'graduation aspirations' and items 4 to 8 with what we might describe as 'important skills'. We also computed the α, α_s and ω_t coefficients for both the first set of 24 responses which all came from our 3rd and 4th year Engineering students and for the full set of all responses which included responses from students who had experienced PBL in other programmes and at other institutions. The values of ω_t were encouraging in the sense that with the exception of test 10, they were within the range of values which Revelle (2009) associates with reliability.

The responses to the remaining five questions suggest that a significant majority of the students attach high value to all of these skills typically associated with PBL. In particular, the following interpretations can be made:

- A very substantial majority of the students place a very high level of importance on being able to apply their theoretical knowledge to solve real-world problems.
- A substantial majority of the students recognize the importance of project management and teamwork skills.

These are complementary interpretation points in the sense that the students recognize the fact that the solution of many real-world problems requires a combination of applied theoretical knowledge, project management and teamwork skills.

As shown in Appendix 1, the above attitudinal interpretations are reasonably consistent across the various sub-groups who completed the questionnaire although the numbers in some of the sub-groups is too low for statistical significance. It is however consistent with similar analyses of student attitudinal data from the ISSE as discussed in section 4.1.1 [ISSE 2015a, 2015b, 2016].

The qualitative questionnaire feedback correlates strongly with the above findings and further reinforces the importance of teamwork and cooperative or peer-learning and skills development as characteristics of PBL which the students attribute to their success. Table 5.3 contains a summary of the responses to each of the qualitative questions. Note that in Q2, we deliberately left the 'PBL' acronym undefined to explore the student interpretation of it.

Q2. Describe briefly what the acronym 'PBL' means to you.
There was a roughly 50/50 split between a problem-based learning and a project-based learning interpretation. Many students highlighted the teamwork and problem solving concepts. A number of students compared it to lectures, expressing a strong preference for the PBL approach although approximately 25% of the students saw the PBL as an opportunity to apply their lecture theory in solving a problem. The fact that they got to tackle 'real-world' problems was also expressly preferred by approximately 25% of the students. Representative sample responses included: *PBL is vital for bringing what is learnt in the class room to real world applications* *As a team, this problem is broken into smaller, more feasible problems, which are solved part by part until the main problem is solved.* *I think it is a vital way of learning compared to book learning, you are integrated into the how you would be in the workforce, dealing with other team members and applying skills you have learnt to find a solution to a problem* *Project Based Learning is a method of learning evaluated by continuous assessment that involves team based projects where the participants in a team work towards a common goal and document their progress and experience through reports and presentations.* *PBL is Problem Based Learning in a team project which can also be described as Project Based Learning*

Q3. What in your opinion/experience are the main characteristics of PBL?
As can be seen in Appendix 2, many of the responses to this question were quite comprehensive having an average word count per response of 79 (the corresponding figures for Q2 and Q4 were 37 and 58 respectively). Similar to question 2 above, the group or teamwork concept featured strongly here too with 19 out of 25 students (76%) specifically identifying teamwork as one of the main characteristics of PBL. While most comments relating to teamwork were very positive regarding its effect on learning and skills development, there were nonetheless some references to pitfalls associated with group project work such as *'those who are willing to work and those who are willing to let them'* and *'…having to work with people who don't put any work in'*. One student requested that team sizes be kept small (3-4 students) and that the team selection process be amended *'to sort teams in to groups of individuals with similar work ethics'*. Another student highlighted the sense of pride and feeling of satisfaction he got from completing the large scale PBL projects. Other representative sample responses included: *it [PBL] is actually quite enjoyable* *The "Hands on" aspect is extremely beneficial. Learning from a book will never match trying something in the physical world* *Even for academic / theoretical problems, the physical act of arguing out your ideas with your peers, listening to their take on things, agreeing to meet up whenever you have delved deeper into the issue helps to solidify your knowledge* *The act of figuring out a solution to the problem by applying theory is by far the most beneficial aspect of the PBL process* *Participants must find the right questions to ask (which requires a high degree of creativity), and because they themselves are asking the questions, they are more likely to truly understand the answers that they find.*
Q4. What characteristics (if any) of PBL do you attribute to your success in your engineering programme?
Although many students indicated a range of characteristics, again the stand-out characteristic was that of teamwork with 15 out of 25 students (60%) specifically attributing their success to it. Other characteristics which featured strongly in the Q4 responses were report writing and presentation skills each at 4 out of 25 students (16%). Representative sample responses included: *PBL is by far the closest thing to real industry experience that I have come across* *Almost everything I've truly learned in this programme came from PBL.* *Although it is important to have faith in your teammates, PBL shows you that the most reliable person is yourself.*

The collaboration between students attempting projects is very effective because students interacting with each other on a "one to one" basis results in students learning from each other a lot more effectively than a lecturer because their focus is on their partner explaining something instead of trying to listen to a lecture while looking at a presentation. *It also brought the whole class a little closer together; I believe we all helped each other out a good deal more because of the PBL. It even helped us in unrelated modules.* *PBL is probably the most useful and important part of my degree in aiding my understanding for how things I have learned in theory practically work.* *I felt like PBL 'rounded' my skillset*

Table 5.3 - summary of responses to qualitative questions

The preliminary questionnaire feedback analysis shown above highlighted the perceived importance of teamwork as a key characteristic of PBL which students attribute to their success on our engineering programme. This finding is consistent with the literature in the sense that numerous meta-studies have found cooperative learning to be more effective in terms of improved learning outcomes relative to competitive learning [Johnson 1998, Prince 2004]. For example, Springer (1999) looked at thirty seven such comparative studies of students in science, technology, engineering and maths (STEM) and found that the 'small-group learning' approach resulted in 'improved academic achievement' (effect size = 0.51), 'improved student attitudes' (effect size = 0.55) and 'improved retention in academic programs' (effect size = 0.46). Effect size is a popular metric for quantifying the result of an instructional or learning intervention. Effect size is defined as the difference in the means of an experimental or test group and associated control group divided by the pooled standard deviation of the two groups. This means that if an instructional intervention among a test group (such as the introduction of small group learning) resulted in an improvement in the test group with an effect size of 1.0 then this would indicate that the test group outperformed the control group (who didn't experience the small group learning intervention but were otherwise treated exactly the same as the test group) on a particular learning outcome by one standard deviation as a direct result of the instructional intervention. Obviously the change (hopefully improvement) in performance of the test group relative to the control group needs to be measured which in turn depends on the assessment methodology associated with the particular learning outcome of interest. In practice, both the test group and the control group undertake an identical assessment such that the influence of the assessment methodology should average out or be normalized across the two groups. However, a potential flaw with this procedure is that the assessment methodology might be better aligned with the instruction given to one group than to the other. Prince (2004) notes that the above effect sizes reported by Springer are *'higher than those found for most instructional interventions'* (pg 2). Nonetheless, the extent to which the students surveyed attribute their success to teamwork is interesting and prompted us to explore this concept further both in the literature and the follow-up focus group.

5.2 Focus Group

As outlined above, following a preliminary analysis of the initial student survey, we designed the follow-up focus group questions and funnelling guidelines to investigate the teamwork concept further and to identify specific aspects of teamwork which the students attribute to their success in a PBL module. Appendix 2 shows the follow-up focus group questions along with the funnelling guidelines for the focus group facilitator. Also shown in appendix 2 is the full transcript of the focus group session. In Table 5.3 below we present a summary of the focus group discussion under each question as well as some specific points which emerged as a result of the funnelling.

1. Based on your PBL experience, what makes a PBL group succeed in achieving their project goals? Discuss
The importance of both individual (self) as well as collaborative (group) learning was mentioned here. *'Everyone (in the group) always wants to do well'* and a number of success factors of working on a group project were specifically mentioned e.g. supportive group aspirations with everyone wanting to do well and no one wanting to let the group down; the opportunity to apply theory to solving a real problem, building things and doing *'practical stuff'*. The Importance of documentation too was also highlighted as a success factor e.g. meeting minutes, planning and internal reports. The workload associated with such documentation would be *'much more difficult'* if it had to be done individually. The focus group highlighted Facebook as an important communication tool in their success. The fact that it was a student-only *('lecturers can't see it'*) forum removed what they called *'the shyness factor'*. They also found Facebook to be a more convenient communication tool than Moodle because they'd *'be on Facebook anyway'* and because of the instant notifications feature they'd look at project-related postings immediately because they'd *'want to know what it is'*. The group did note however in their concluding comments that they found face-to-face communication to be much better than online.
2. Based on your PBL experience, what makes a PBL group NOT succeed in achieving their project goals? Discuss
Group size was noted as a factor here. Specifically, the focus group felt that if a PBL group is too big then *'communication doesn't function as well'* and *'some students don't feel there's a need to take it as seriously'*. They felt that the best group size was 4 or 5. The attitude of the individual members of a PBL group can also cause the group not to succeed. If one team member doesn't pull their weight this can have a negative knock-on effect on the others whereby they'll slow down too on the basis that why should I work hard if they're not pulling their weight. It was noted that if there's even one group member not good on time management then this can have a negative impact on the success of the group. This point emerged again under question 4 where it was noted that *'individual attendance makes a statement of it's own … if you don't attend regularly it indicates that you don't have an interest in the project'*. Actions speak louder than words – and sometimes inaction tells a lot about someone's attitude.

Gender, religion and background don't make any difference to group success but it makes sense to try to allow the individual team members to work to their strengths. Some of the recording was unclear here (see appendix 3 transcription) although on a repeated listen to this section (17 min) it became clear that the focus group facilitator interpreted the value of rotating roles within a group but also noted that *'if there's an assessment involved, you're better to let people play to their strengths, rather than to say you've learnt it all'*.
3. If a PBL group is not working well together, what do you think can be done to improve things? Discuss (funnelling: what can be done by the group members? what can be done by the facilitator?)
The focus group noted that in this scenario they would *'probably have a meeting and talk about it'* in an effort to improve the team performance. Such meetings could become heated but you have to be *'up front'* about it. They could ask the facilitator to help them to resolve an issue or to mediate in such a meeting but in general they felt that it was really up to the group to fix it themselves. Another approach suggested was to *'elect the person who doesn't have a disagreement to distribute the work for the group'*. As a last resort, the group may have to split up in which case they have to inform the facilitator and the two sub-groups still have to finish their project i.e. submit reports for assessment and attend interviews. The value of putting in place explicit structures was noted e.g. *'about the time you meet each week and what work should be done', 'meeting minutes including action items', 'agreed deadlines'* etc. A difficulty noted here was that the students were *'always rushing to finish projects and assignments'*.
4. Based on your PBL experience, how do the individual personalities in a group influence the overall success or failure of the project? Discuss.
It was felt that the individual personalities within a group can have a strong influence on the success or not of the group. If two individuals in a group don't get on well, then this will impact negatively on the group performance. It was noted that a group needs a leader in order to establish direction. However, the wrong leader could result in *'the group building up a ball of anger'*. In general, an obvious leader emerges naturally. The group felt that self-selection of PBL teams was the best way to avoid personality clashes. It was also noted in the concluding comments that individual attitude and work ethic had a stronger influence on group success than did individual personality e.g. *'Individual attendance makes a statement of its own, if you attend most of them, you're indicating that you're interested in getting the work done'*. On the final question of preference between face-to-face versus online communication all of the focus group members felt that *'face to face is much better'*.

Themes for possible funnelling questions in any of the above discussions (especially Q4):
• Individual personalities and how they affect group dynamic Personality clashes can have a strong negative influence on the success of a PBL team and one way to avoid this is group self-selection. However, individual attitude and work ethic had a stronger influence on group success than did individual personality (see Q4 summary feedback above). • Pulling your weight in a group project See Q2 summary feedback above. Again individual attitude and work ethic emerged as important success factors. However, these important attributes can themselves be influenced by program design issues such as PBL group size and the time (and marks) allocated to the project or the other demands on the time of the students who were *'always rushing to finish projects and assignments'* (See Q3 summary feedback above). They noted the importance of time management by all members of a group. They felt that the ideal group size was 4-5 members. • The role of writing (documentation) in PBL The importance of documentation did arise a number of times throughout the focus group session, for example, during the Q1 discussion it was noted that in the team project scenario *'many people can record results'* leading to a *'good deal of documentation'* which would be *'much more difficult (to produce) individually'*. The types of documents specifically referred to included: *'project planning and internal reports'*, meeting minutes including actions (see Q3) *'so everyone can look them over in case they have missed anything'*, *'the report'* (Q2 discussion) which we assume refers to the final group project report. In relation to the explicit documentation of *'guidelines/terms of reference for hitting deadlines etc'* which was discussed under Q3, it emerged that this was *'more informal agreement, more implicit in the group'* rather than having such agreed guidelines/terms of reference explicitly documented.

Table 5.4 - Summary of Focus Group Discussion

5.2.1 Focus Group Analysis

A number of interesting points emerged from the focus group. Many of these points were consistent with the survey feedback e.g. the attribution of teamwork by the students as a strong factor in their success in PBL and the recognition that they can achieve much more by working systematically together than they can individually. Two new findings emerged, however, namely Facebook and attitude.

Although the University virtual learning environment (VLE) (Moodle) enabled each group to communicate online they unanimously preferred to create a private or closed group on Facebook and use this for remote communication. Two reasons cited for this preference for Facebook over Moodle were that their facilitator couldn't see the details of their online communication and the fact that it enabled closer to real-time communication because they were all on Facebook all of the time and would therefore view a project-related posting immediately. This is an interesting finding particularly in light of the fact that in many of the PBL modules which these students had taken, regular posting to their group project discussion forum on Moodle was an actual assessed requirement.

The finding relating to group member attitude is possibly more significant in the sense that this factor can have a profound effect on the entire group dynamic. If one member isn't *'pulling their weight'* on the project this can lead to conflict within the group. This can also cause the other group members to *'not feel as obligated to work'* (see Q2 discussion in Appendix 1) which in turn will have a negative impact on the team performance. Although Prince (2004) has shown that active learning can have a positive influence on student attitude and engagement in engineering education, and indeed few will dispute such a finding, nonetheless the focus group discussion suggests that this positive influence is by no means guaranteed and is itself very much dependent on a number of characteristics of the active learning environment. For example, group size and group selection process affect student attitude with students favouring a group size of 4 to 5 members and they also prefer self-selection to avoid personality clashes. Time constraints were noted as a difficulty for the students in progressing their projects. This finding is consistent with Graaff (2003) who notes that many PBL implementations allocate insufficient time and marks to the PBL component of the programme. In our current programme, which all of the focus group students have experience of, the ratio of time and marks allocation between the PBL module and parallel taught modules is 10/20 i.e. a 10 ECTS credit PBL project module is undertaken in parallel with four 5 ECTS taught modules. This is still some way off the recommended 15/15 split needed in order to provide scope for students to achieve the skills development outcomes associated with PBL. Another useful finding of both the student survey which was reinforced in the follow-up focus group discussion is that the students see the PBL modules as an opportunity to apply theory to solving a real problem *('implement what we learn and do practical stuff'* – Q1 discussion Appendix 2). This is much more likely to happen if the engineering programme design is based on close coordination between each PBL project module and the taught modules which are taken in parallel (or before) with it. In PBL best practice this is achieved via thematic semesters [Graaff 2003, Kjersdam 1994 p. 18] whereby each semester is designed around a discipline-specific theme and which makes *'project supporting course'* [Moesby 2002 – pg 147] content available to the students early in the semester. Such programme design criteria maximize the linkages between the project supporting courses and associated PBL project and in turn provide opportunities for the students to apply taught module theory in their PBL projects.

Another interesting finding of the focus group which was not evident in the survey feedback was a reluctance on the part of the students to explicitly document their *'guidelines/terms of reference for hitting deadlines etc'* (Q3 discussion) in favour of a less formal or more implicit approach. This finding suggests that the importance of being explicit about these terms of reference may need to be emphasized in the PBL student handbook and regularly reinforced by PBL facilitators, particularly in the early semesters of the programme. This finding highlights the importance of two related factors, namely, a well prepared PBL student handbook and PBL facilitator training/experience.

5.3 Team-Based, Collaborative & Cooperative Learning

Based on the above preliminary analysis of the survey data, we also revisited the PBL literature with a specific focus on collaborative and cooperative learning often associated with effective teams. This caused us to look again at what looked like one of many variations on PBL, namely, team-based learning [TBL website]. Team-based learning (TBL) is a highly structured variation on PBL based on four underlying principles (Michaelsen & Richards 2005), namely:

1. *Groups should be properly formed (e.g. Intellectual talent should be equally distributed among the groups). These teams are fixed for the whole course.*
2. *Students are accountable for their pre-learning and for working in teams.*
3. *Team assignments must promote both learning and team development.*
4. *Students must receive frequent and immediate feedback.*

The above principles are very much in line with PBL best practice which suggests that TBL is one of many variations within the PBL approach [Kolmos 2014 Chapter 8 Introduction]. The highly structured nature of TBL is reflected in its 'three-step cycle', namely, prescribed pre-reading before class, in-class readiness assurance testing, and application-focused exercise. However, the above structure suggests that the TBL approach is largely teacher-directed in the sense that the teacher specifies the pre-reading material for each class and prepares the in-class readiness assurance test. This makes TBL significantly different from PBL which fosters student-directed learning. Nonetheless TBL is popular in medical education [McInerney and Fink 2003] where it enables peer learning by encouraging group discussion and also allows one lecturer to manage a large class. McInerney and Fink (2003) introduced TBL into an undergraduate microbial metabolism-physiology course and found that initially it made little difference to the final examination scores. However, the following year they included '*challenging team projects*' into the course which resulted in '*significantly improved final examination scores compared to the previous year without team projects*' (pg 3).

Our interpretation of TBL is one of guided enquiry as shown in Figure 5.1 which is probably more effective in the early semesters of an engineering programme where mastery of discipline knowledge and fundamental principles is a priority. However, towards the latter semesters of such a programme, greater emphasis needs to be placed on the application and adaptation of these principles to new situations. This interpretation is consistent with Panitz (1999) who highlights the need to consider a more structured teacher-directed approach (cooperative learning) to PBL in the early semesters and move towards a less structured more student-directed approach (collaborative learning) in the later semesters.

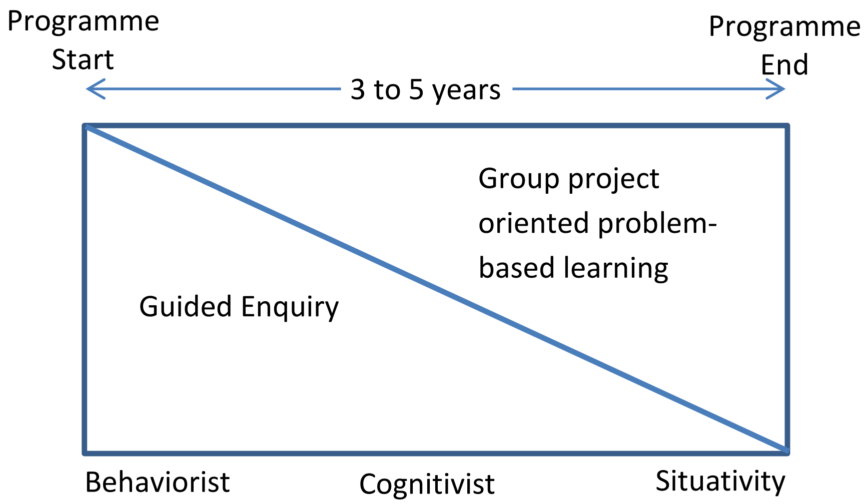

Figure 5.1 Full Programme Instructional Design Model [BL MPBL Sem1 Course 2 Session 3 Reflection]

Panitz (1999) also poses an important question related to cooperative and collaborative learning, namely, (Pg 8): "*How can we use our awareness of the social nature of learning to create effective small group learning environments?*". Panitz also highlights a serious problem with bad practice bolt-on PBL, namely, (Pg 12): "*Frequently, when students or teachers hear the phrase collaborative learning, they automatically assume a work group context, harken back to their own unpleasant experiences with work or study groups, and dismiss the notion of collaboration as an unworkable approach that attempts to transfer the burden of teaching from teacher to student. Such anxiety is worth noting because it represents an acute misunderstanding of what has become a most viable approach to teaching and learning.*"

Katzenbach and Smith (2006) looked in detail at the characteristics of what they called high performing teams in real work environments. They use the so-called team performance curve shown in Figure 5.2 to explain the difference between a working group and a high-performance team. They also argue that "*real teams do not emerge unless the individuals on the team take risks involving conflict, trust, interdependence and hard work*" (Chapter 6 opening paragraph).

Katzenbach and Smith (2006) also offer the following eight guiding principles to help a working group to move up the team performance curve (Chapter 6):

1. *Establish urgency and direction.*
2. *Select members based on skills and skill potential, not personalities.*
3. *Pay particular attention to first meetings and actions.*
4. *Set some clear rules of behaviour.*
5. *Set and seize upon a few performance-oriented tasks and goals.*
6. *Challenge the group regularly with fresh facts and information.*
7. *Spend lots of time together.*
8. *Exploit the power of positive feedback, recognition and reward.*

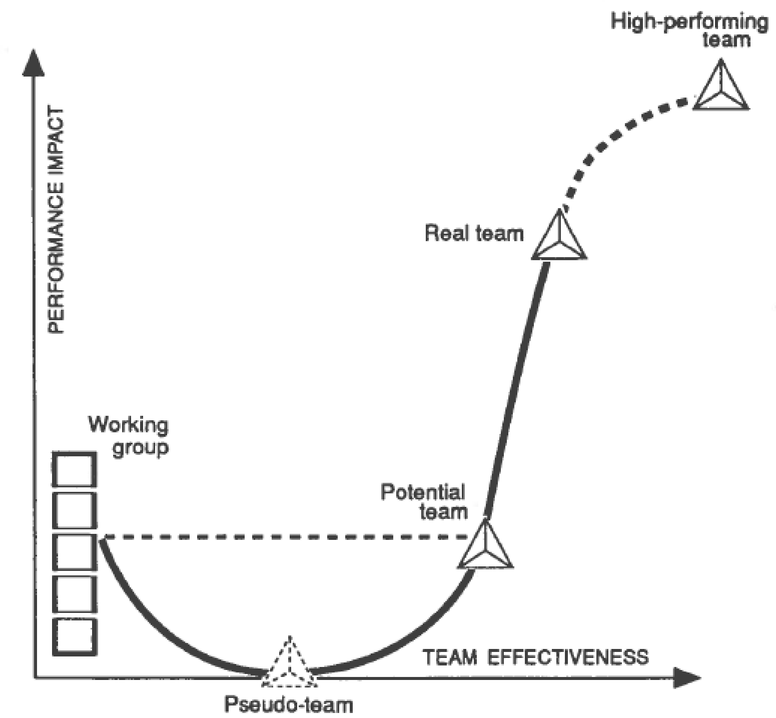

Figure 5.2. The Team Performance Curve, Katzenbach and Smith (2006)

The above principles suggest the need for substantial group projects in order to provide sufficient scope to accommodate the principles. They also highlight the importance of an experienced facilitator, particularly in the early semesters of an engineering programme as a typical group of first year students are highly unlikely to spontaneously comply with these principles. The challenge for the effective facilitator is not to get stuck into the project with the group but rather to 'observe and comment' in such a way as to gently guide the group towards compliance with the principles while at the same time allowing them the scope to self-direct their own learning and process competency development.

Jollands and Parthasarathy (2007) looked at the way in which PBL teams are formed and the effect this has on their achievement of learning outcomes. They tested three alternative team formation methods on an undergraduate chemical engineering programme, namely, free choice, constrained choice, and random allocation. They found that *'small diverse teams are better than large homogenous teams'* (p. 333) irrespective of how the teams were actually formed.

6.0 Discussion and conclusion

There's a lot of literature relating to indicators of success from the engineering educator perspective and the employer perspective but not so much based on the student perspective. Some might argue that students would not have sufficient training and/or experience to offer an 'educated' perspective on the matter. However, our preliminary research into student views relating to indicators of success in engineering education suggests that undergraduate students are very much in tune with the key skills required for a successful career in engineering and that they would very much welcome the opportunity to develop these skills during their education programme. Unfortunately, not all engineering programmes offer these opportunities for a variety of reasons including:

- *'Over-stuffed curricula'* [Graaff 2003 – p. 661]
- Faculty unconvinced about the importance of these skills [Barrows 1996 p. 4]
- Faculty not comfortable to provide training and assessment of many skills which they themselves never formally acquired during their education.

One possible reason for the slow uptake of properly integrated PBL in engineering education programmes is that many faculty are themselves the more 'successful' graduates (from the educator's perspective!) of traditional education systems. These same faculty members in time move up the academic career path to become education programme policy makers. As long at this situation prevails, it is highly unlikely that the coordinated team effort needed among faculty to integrate key skills development opportunities in line with best practise [Kolmos 2014] into the curriculum will take place. The more common scenario often associated with a small number of interested faculty is a 'bolt-on' PBL module which regularly fails and even gets PBL a bad name in the process. This highlights the importance of being very clear about the characteristics of best practise in PBL and the dangers of 'bolt-on' PBL.

The widely accepted most valid approach to analysing the effect of a learning intervention is to first divide the class into two groups, namely, an experimental group and a control group. The learning intervention is then applied to the experimental group but not to the control group. The two groups are treated identically in all other aspects of the course including taking an identical assessment to measure their level of achievement of the target learning outcomes. Mayer used this research methodology to derive his principles of multimedia learning [Mayer 2001]. Freeman (2014) conducted a meta-analysis of 225 studies which compared a variety of active learning interventions with traditional lecturing in the science, engineering and maths disciplines. Although he concludes that '*active learning is the preferred, empirically validated teaching practice in regular classrooms*' (p 8410), he also notes that '*the results raise questions about the continued use of traditional lecturing as a control in such research studies*' (p 8413). For example, if the identical assessment which is applied to both the experimental and control group is better aligned with the traditional lecturing delivery then this could disadvantage the measurement of the effectiveness of a PBL intervention via written exam assessment. Further, if the purpose of introducing a PBL intervention is to support the development of teamwork skills, for example, then the written exam may not be the appropriate assessment methodology with which to measure the effectiveness of the PBL intervention. One possible way to normalise this alignment bias might be to apply two assessment methodologies, one aligned with the experimental group and the other aligned with the control group, for example, a written exam and an interview and to average across these two assessments.

As Cowan says, assessment drives learning. If we can't measure the effect of a learning intervention with a reasonable level of accuracy, then it's impossible to develop an evidence base upon which to support or reject that learning intervention. The benefit of a written exam is that it represents a robust paper trail upon which to base an assessment. But a group written report based on a PBL project represents a robust paper trail and a short interview of each individual group member can quickly ascertain their level of achievement of the learning outcomes.

In her keynote address in Dublin in 2014, Kolmos noted the importance of evidence in PBL research. The language of such evidence is often referred to as learning analytics. Unfortunately, according to the Learning Analytics Community Exchange (LACE) *'there is no universally agreed definition of the term 'learning analytics''* [LACE 2016]. One popular definition states that learning analytics are *'the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs'* [Siemens 2011]. Siemens also notes the close relationship between learning analytics and Educational Data Mining (EDM 2016) which is *'an emerging discipline, concerned with developing methods for exploring the unique and increasingly large-scale data that come from educational settings, and using those methods to better understand students, and the settings which they learn in'*. In relation to the use of EDM for learning analytics he also notes that '*assessing real learning impact is hard – both on a practical, logistical level (as it requires longitudinal studies) as well as on a more methodological level (as impact is 'messy' and it is difficult to isolate the effect of the intervention that we want to evaluate)'*. He also states that '*the danger of presenting meaningless eye candy or networks that confuse rather than help is all too real'*. Revelle (2009) highlights an example of such confusion in his comparison of the various metrics used in the analysis and interpretation of educational data (see section 4.1.1). As long as such confusion prevails among the learning analytics community it's unlikely that the evidence which Kolmos refers to needed to convince those faculty which Barrows refers to will be generated.

7.0 Further work

Recall the original research question:

What characteristics of PBL (if any) do successful students attribute to their success on an engineering programme?

It might be interesting to carry out a complementary study of experienced PBL faculty and ask them, for example, what characteristics of PBL (if any) do they attribute to the success of their students on an engineering programme? From a very small phenomenological research perspective I already have at least one piece of data relating to this question. This piece of data came from a chance conversation in November 2011 with an experienced PBL facilitator who just happened to mention that in their experience the single most important characteristic of PBL was the peer-learning! Statistically one piece of data isn't worth much but whenever anyone asks me why I did the masters in PBL the first thing that always comes to mind is that chance conversation and the above point about peer-learning. I wonder does the fact that the same PBL facilitator had 37 years of experience (having first enrolled as an engineering student in 1974!) of the Aalborg model increase the statistical significance of their opinion. Probably not, but if this chance conversation can have such a stimulating effect on me then maybe it would be a useful exercise to design a study aimed at systematically collecting and analysing the opinions of a statistically significant cohort of experienced PBL facilitators in relation to the above research question. If many of them feel the same about the peer-learning characteristic of PBL then the key finding of the study might be something like: '*based on over 1000 years of PBL facilitator experience, the single most important characteristic of PBL is the peer-learning*'. I wonder would that stimulate the interest of those unconvinced faculty which Barrows (1996) referred to – probably not!

Clearly further work is needed to address the confusion discussed above surrounding the most appropriate metrics for use in problem based learning analytics. This will require a concerted interdisciplinary team effort with input from experienced PBL practitioners, learning analysts, statisticians and software developers. Such a team might be able to develop an open-source R package associated with best practice in PBL and to easily compute the necessary problem based learning analysis metrics needed to generate real evidence of the effectiveness of this method.

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Appendix 1 – Initial Survey

Questionnaire aimed at 3rd & 4th year BE(Eng) students

Research Question

The purpose of this questionnaire is to gain insight into the following research question:

What characteristics of PBL (if any) do successful students attribute to their success on an engineering programme?

Please indicate (√) which year of the BE(Eng) programme you are in: 3rd year ☐ or 4th year ☐

Q1. Please indicate (√) on a scale of 1 (not so important) to 5 (very important) how important the following indicators of success are for you:

	Not so Important 1	2	3	4	Very Important 5
Graduating with first class honours					
Graduating with at least a 2.1 honours					
Just passing my exams and graduating					
Developing my teamwork skills					
Developing my presentation skills					
Developing my report writing skills					
Developing my project management skills					
Being able to apply my theoretical knowledge to solve real-world problems					

Q2. Describe briefly what the acronym 'PBL' means to you.

Q3. What in your opinion/experience are the main characteristics of PBL?

Q4. What characteristics (if any) of PBL do you attribute to your success in your engineering programme?

Follow-up focus group questions aimed at PBL students

Research Question

The purpose of this interview / focus group is to gain insight into the following research question:

What characteristics of PBL (if any) do successful students attribute to their success on an engineering programme?

1. Based on your PBL experience, what makes a PBL group succeed in achieving their project goals? Discuss

2. Based on your PBL experience, what makes a PBL group NOT succeed in achieving their project goals? Discuss

3. If a PBL group is not working well together, what do you think can be done to improve things? Discuss (funnelling: what can be done by the group members? what can be done by the facilitator?)

4. Based on your PBL experience, how do the individual personalities in a group influence the overall success or failure of the project? Discuss.

Themes for possible funnelling questions in any of the above discussions (especially Q4):

- Individual personalities and how they affect group dynamic
- Pulling your weight in a group project
- The role of writing (documentation) in PBL

Questionnaire Responses from 3rd & 4th year BE(Eng) students

Q1. Please indicate (√) on a scale of 1 (not so important) to 5 (very important) how important the following indicators of success are for you:

	Not so Important 1	2	3	4	Very Important 5
Graduating with first class honours	0/25	1/25	3/25	11/25	10/25
Graduating with at least a 2.1 honours	0/25	0/25	2/25	6/25	17/25
Just passing my exams and graduating	11/25	6/25	4/25	0/25	4/25
Developing my teamwork skills	0/25	1/25	1/25	12/25	11/25
Developing my presentation skills	0/25	0/25	4/25	10/25	11/25
Developing my report writing skills	0/25	0/25	3/25	10/25	12/25
Developing my project management skills	0/25	0/25	2/25	9/25	14/25
Being able to apply my theoretical knowledge to solve real-world problems	0/25	0/25	1/25	4/25	20/25

Q2. Describe briefly what the acronym 'PBL' means to you.

PBL means to me, means a group of individuals coming together to accomplish a goal and to improve their team skills along the way such as communication, presentation and work ethic.
To me project based learning is vital for bringing what is learnt in the class room to real world applications. It is important to know and understand the theory but also how to apply it.
PBL = Problem Based Learning. I first heard of this while at Intel. Small groups tackle project-type problems, learning as they go. It is far more "hands on" than classroom lectures.
Problem based learning, a real-world learning module to develop our skills and further our theoretical knowledge of electronics. Working together in an environment and set up the same as would be if we were to be in a company, solving problems.
Project Based Learning
It is a module that can develop your problem solving, co-operation skill. And on top of that, you will be also to develop teamwork, presentation and listening skills.
Project/Problem based learning. The difference in my eyes is that a project can be undertaken to which a solution exists and therefore it is not a problem. Understanding that solution would be a project not a problem. Sometimes a problem may need to be solved in the course of the project and so it'd be problem based.

It is a process that gives students the opportunity to apply theory to solve a defined problem.
Problem-based learning; a way of learning where a broad and challenging problem is put forth to be solved by a team. As a team, this problem is broken into smaller, more feasible problems, which are solved part by part until the main problem is solved. The solution is then assessed based on an end result, that is usually very original and a normal conversation to judge what individual members of the team did and what they understood.
For me PBL is a way the course can offer a flavour of the real world. Everything from Business and Marketing to Electronics is covered under the umbrella that PBL is.
Problem-based learning: A way in which students learn about an area of their course through the experience of solving an open-ended problem. This is usually done through project or lab work in Electronic Engineering.
Project based learning is a module more focussed on learning from your peers than from a lecturer. It allows you to do your own research and apply what you found through a bit of trial and error, learning from your mistakes. If you apply your knowledge and fail, you are more likely to learn from it and not repeat that mistake again.
Project based learning is not only improving your electronic skills but also developing other important life skills such as team work, time keeping, report writing and project management. I think it is a vital way of learning compared to book learning, you are integrated into the how you would be in the workforce, dealing with other team members and applying skills you have learnt to find a solution to a problem. Project based learning is where you learn by doing things yourself or as a team (peer based learning).
Project Based Learning is a method of learning evaluated by continuous assessment that involves team based projects where the participants in a team work towards a common goal and document their progress and experience through reports and presentations.
To me it means problem based learning where a student is given a problem to solve. I believe students can take many different paths to solving the same or similar problems. It is more akin to real world learning and much more interesting than lectures. I believe that students can become much more involved.
Project based learning is the way in which we develop a multitude of skills through a group project. You learn much better by discovering the answers rather than having them given to you and so with PBL you are set to discover the answers.
Problem based learning: You take a problem and learn from the methods used to solve that problem.
PBL to me feels like a collaboration of a group of students to come up with an intelligent based solution to a given problem while also working collectively as individuals and applying the some background knowledge into the project as well as common sense.
Problem-Based Learning

PBL can be seen as both project based learning and problem based learning as both problem solving and project management skills are required for the subject.
Project based Learning. For me it means encountering a problem and finding a solution for that problem, be it either sitting down and working through it until a resolution is found, or finding someone and asking them for a solution. The teamwork end comes incredibly beneficial when explaining your findings to teammates.
Project Based Learning, being able to put the theoretical knowledge gathered so far into practical use and understanding/realising the real world applications of the degree (ideal vs. real, adapting to a problem and solving, being creative in your solutions working in a team, etc.)
Learning how to apply the knowledge you have acquired in actionable real world steps, leading to a deeper understanding of what you know and enhancing your understanding of the required steps in the completion of a successful project.
PBL is Problem Based Learning in a team project which can also be described as Project Based Learning

Q3. What in your opinion/experience are the main characteristics of PBL?

Learning how to apply the theoretical side of what I had learned in class to a practical application to achieve a larger goal.
The main experience of PBL is learning to work as part of a team, problem solving, time management, presentation and report writing skills. All these skills are very important to know when going out to work as an engineer.
• Freedom / flexibility to dig into a problem at your own pace, as opposed to structured lectures which may be too fast / slow for individual students. • Group learning - This really helps to disperse knowledge throughout the group. Everybody learns more-or-less in parallel, as opposed to a few top students and a few weak ones. Good for social / team skills too! • The “Hands on” aspect is extremely beneficial. Learning from a book will never match trying something in the physical world. Even for academic / theoretical problems, the physical act of arguing out your ideas with your peers, listening to their take on things, agreeing to meet up whenever you have delved deeper into the issue helps to solidify your knowledge. You can’t really do these things in a lecture environment. It feels like you are not just ticking boxes to pass an exam, you are sinking your teeth into an issue that needs to be resolved!
Team work development, presentation development, report writing development, and hands on learning of electronics.
It emulates real world situations, helps improve your methods of research, self learning and group work
In my opinion, our creativity and ideas can put into practice are the main characteristics’ of PBL

Brief phases of a development of an idea, brief phase of working a solution to that idea. Long phase of report writing. Short phase of presentation preparation. The fact that the marks in the module go for the reports and their content is understandable from an educators viewpoint but the collective grades given bear no resemblance to the input of the individual group members or the advances made towards engineering the original solution set out by the group. Also each facilitator takes a different viewpoint in feedback from submitted draft reports, this can lead to a team satisfying one facilitator views while alienating two others. I understand this is personal preferences of individuals but it can effect grades badly.
The act of figuring out a solution to the problem by applying theory is by far the most beneficial aspect of the PBL process, as it gives students the experience of working with new hardware and software in the scope of a large scale project. Report writing and project planning are also fairly beneficial. The additional “baggage” tacked on to PBL in the form of large teams, team management, business reports etc. are less beneficial.
Creativity is a core characteristic of PBL, which is fitting because it is also the most important characteristic of a good engineer. PBL truly encourages participants to think, because the solution will always be the team’s own interpretation of the problem. Participants must find the right questions to ask (which requires a high degree of creativity), and because they themselves are asking the questions, they are more likely to truly understand the answers that they find. Also since there is a well-defined context, theoretical concepts are more easily understood because they are actually applied towards achieving a real-world end result. Team-work and organisation skills are also very important characteristics in PBL, as the efficiency of finding a solution can be improved significantly if each team-member is contributing significantly. This is in stark contrast to an exam situation. In the exam scenario participants are assessed on what they can remember instead of what they understand, and creativity is of practically no help due to time-constraints and reliance on memory. In most cases questions in an exam have virtually no context, and are probably impossible to answer without having seen a past solution. The best tactic for doing well in an exam is to do past papers i.e. learning off methods of doing things, without actually understanding the origin nor the true purpose of each step. After exam week, these methods will promptly be forgotten entirely and because students have no motivation to understand them, they will essentially have learned nothing at all.
PBL grants students an insight into what working in the industry is like on a smaller scale. It offers students a chance to apply all (if any) theoretical knowledge of electronic engineering. Gives them a chance to work on their business and management skills in parallel with the core aspects of the EE course. I think the main focus of the course itself is to see how well students can work in a group and complete and compile a decent project/report.
Enhancing your “academic” knowledge by putting it to practical use while developing other important skills like teamwork skills, critical thinking skills, management skills, presentation skills and report writing skills
Team working skills are important to develop during PBL. This is also a very key skill to have later in life when applying for jobs. Report writing is also another skill that’s refined during the project. It is something that is essential in any project. To be able to plan a report out, reference correctly and format correctly. Problem solving skills is also tested during the project. Building something, having it not work correctly and then troubleshooting. This is valuable to have when undertaking any project that involves building a product.

Time keeping, report writing, work being fairly distributed, team meetings, research.
Problem solving skills, team building skills, peer learning and project management.
With some exceptions, Teamwork is difficult to maintain because of the differences in work ethic among students. The statement “There are two types of students: Those who are willing to work and those who are willing to let them” could not be more true. Often what can happen is (especially in large teams) only a few of the students (for example only 2 out of a team of 5 or 6) are covering the bulk of the work. A team size of 4 People is the maximum size that should be allowed in a team in my opinion so ideally 3-4 students for the team numbers. Teams that have more than 4 people tend to result in a mentality where an individual feels as though they don’t need contribute because there are enough members completing work for a team. In regards to students working in pairs, students progress through work fine when they are allowed to choose their partner but when students are allowed to form big teams by direct choice, a repeated habit of a group of friends join up where one or two of the students working the most are more than happy to “carry” their team mates by completing all of the work for them. PBL projects are better handled when students forming teams are based off of having selected a common project.
The main characteristics of the PBL are the chance to work in a team, it can make the semester seem a little easier as your team mates can help and support you along the way. Also, it is very nice to get the project ‘out of the way’ before exams start. Two less exams eases the pressure at the end of semester.
Group work, you work hard together or you fail together. You learn to be a team played in a technical sense and learn your colleague’s weaknesses and strengths. With your own in mind you work together to maximum everyone’s abilities.
Teamwork, doing projects in a team allows for more learning opportunities that would not exist otherwise, mainly peer learning. It allows us to do something a little more tangible, that puts into practice the theory we learn in other modules.
Coming up with an idea early is key and making sure that everyone is satisfied with the idea and how the work is going to be done to complete the idea.
▯ Students use real-world problem solving to learn contexts and critical thinking skills. ▯ Students rely on problem-solving to drive the curriculum rather than lectures ▯ Students are presented with ill-structured problems to solve - there is not meant to be a single solution, and as new information is gathered in re-iterative process, the perception of the problem together with the solution changes. ▯ PBL is learners-centred - Learners are progressively given more responsibility for their education and become increasingly independent of the teachers for their education. ▯ PBL produces independent, life-long learners - student continues to learn in life and in their careers.
The main characteristics of PBL are:

- **P**lanning: Unlike conventional classes, teams must create a work plan and divide up the total work to deliver their PBL projects.
- **R**esearch: Teams must perform research on their projects topic independently. This is a great way to delve into certain areas of electronics and gain hands on experience.
- **I**nitiative: Most PBL projects won't come to fruition if initiative is not used by students. Project supervisors (lecturers) can try to push students into doing their projects but ultimately students must work by themselves to complete their projects.
- **D**evelopment: PBL is great for developing skills of many forms, problem solving, project management, teamwork etc. By learning through practice, rather than theory, skills are developed quicker and retained longer.
- **E**njoyment: Although the other characteristics might make PBL sound like some vicious work camp, it is actually quite enjoyable. Working and researching on certain areas of electronics can be very interesting, and working with a team, though sometimes problematic, is overall pretty decent craic.

Lastly, a 'side effect' characteristic of PBL is the **PRIDE** that comes with actually completing large scale projects. In college most grades are determined by tests and assignments, and bar the grade itself, it's easy to feel that you haven't really progressed further at all. However by putting skills into practice and coming out with physical results, i.e your project, you get a great feeling of satisfaction as you know your progressing, and gaining skills that are useful.

I think PBL can be broken down into a set of steps. The first is finding a group of people you work well with and that you will be able to rely on to get your tasks done. The ability to rely on your team is important as it will help when trying to keep on top of the work. Next is to come up with a breakdown of how what needs to be done to get to the project done and then to start doing.

Team building and management (communication skills!), organisation and the knowledge of the course. Being able to work with a variety of people with different work ethics and techniques gives the student a chance to experience the working environment in the real world. It also gives them a chance to put different skills into practise while dealing with the unfamiliar situations of team work/projects.

Teamwork, relatively simplistic projects due to timeframe constraints, having to work with people who don't put any work in.

The above factors make them slightly unrealistic compared to what we can expect in a work environment. Sure we will have "short" deadlines in work but the projects will more substantial, would it possible to create one PBL project between 2 modules? Allowing a greater scope? It's also realistic to expect that people will put in different amounts of effort in to a project in a real work environment however it's unlikely that they will put in no effort whatsoever, something I have often come across in PBL. This may not be possible for ethical reasons, but it would be beneficial to sort teams in to groups of individuals with similar work ethics.

- Team Learning
- Better understanding the material by teaching other in the team
- Project/Time Management

Q4. What characteristics (if any) of PBL do you attribute to your success in your engineering programme?

My ability to work an manage a team, prior to PBL I found it very difficult to work with others but now i have a better understanding of what is involved and how to work together to achieve a goal. I have also learned how to deal with and resolve conflict in a team on both a large and small scales.
The characteristics learnt during project work during the course of the engineering programme to date have helped me greatly through the process of completing my final year project.
• PBL definitely helped to improve my teamwork skills. You have to have a certain level of diplomacy when dealing with people. You cannot learn this from a book. • This in turn helped my report writing skills. There is a happy medium when writing reports, you cannot gloss over technical details, but rather they must be delivered clearly for everybody to understand. Not everyone understands Shakespeare, yet it is written in English! Delivery is the key. • PBL definitely helps to improve student’s motivation. Self-learning and accomplishing your task feels like an achievement, especially when the problem is not one you liked. This is in contrast to the “good riddance” attitude which can sometimes prevail after solving an unwanted difficult problem. • PBL is by far the closest thing to real industry experience that I have come across. In industry, you meet with groups of people every day and problems are dealt with by dividing up the work among the participants. People learn from each other and plans change constantly, so you need to be dynamic. PBL is perfect for fostering this.
The team work and presentation skills developed are in my opinion the most important characteristics of the module, they would stand to us the most working in the real world.
Discipline, Time management, report writing, team work, presentation skills and conducting research
I think now-a-day, innovation plays a huge part in the industry and during this module we are able to hypothesize boldly and to experiment rigorous. Students and myself are able to learn main more things that are outside the specs of the course. More involved with people, able to work as a team, just like what would happen if you are working in this sector and you cannot build everything by yourselves.
I feel that the report writing undertaken in the module is, for me, the biggest thing. It improved my engineering vocabulary and allowed me to communicate at a standard that is expected in industry. Implementing the theory learned in class and researched into a project is icing on the cake, and troubleshooting the problems which arose increased my understanding of systems interacting with each other.
The necessity of learning about new theory and electronics, unaided, in order to solve your problem gives the experience of needing to teach yourself, and gives access to knowledge outside of that on the course syllabus.
In terms of success regarding what I have actually learned, PBL has enabled me to properly understand some of the theoretical concepts introduced in other modules, by providing a physical

context through which I could apply the concepts in in the real world. It has also made me more aware of how the concepts can actually come of use in solving real-world problems. Almost everything I've truly learned in this programme came from PBL. Also in terms of the experience itself, PBL has taught me a range of useful skills, from working with others to presenting and being interviewed. In terms of success regarding grades it has consistently improved my yearly average, albeit by very little as exams grades are unfortunately the main metric by which our success in the programme is measured, and are worth significantly more. This is interesting because projects, and not exams, also took up the vast majority of time throughout the programme.
Time management. PBL requires an amount of planning and preparation, many things are happening with each group member constantly and it is up to someone to manage the people and time. Managing time is tough but it really contributes to exam time, knowing how much time to devote to each topic etc. Also the obvious contribution is the in depth understanding of the electronics that is necessary to complete PBL.
80% The majority of my learning has come through practical work and in my opinion that will be more valuable to a person in the working world.
Perseverance. The single most important thing to do during any project. The fun, interesting aspects collide with the tedious and frustrating parts of everything else. Although it is important to have faith in your teammates, PBL shows you that the most reliable person is yourself. Considering most of the engineering programme involves working as a lone wolf.
The engineering program has greatly improved my skills of working with a team and delegating work within a group. Presenting projects , research skills , report writing skills.
In my opinion, problem solving skills is the most important characteristic that can attribute to my success. Memory power is another factor in being successful as remembering the right things at the right time can lead to greater success.
The collaboration between students attempting projects is very effective because students interacting with each other on a "one to one" basis results in students learning from each other a lot more effectively than a lecturer because their focus is on their partner explaining something instead of trying to listen to a lecture while looking at a presentation. Students teaching anything to other students is reinforced learning. Having a facilitator supervising a team is also very effective because mistakes made can be pointed out by a facilitator early and students can rectify their projects as opposed to waiting to be graded at the end of the term (like with an exam) and only then informed that they were wrong when it is too late for them to have a chance to get something completed correctly.
It allowed me to concentrate on the aspects of the engineering programme that I liked and was good at. It also brought the whole class a little closer together; I believe we all helped each other out a good deal more because of the PBL. It even helped us in unrelated modules.
Presentations and interview help a lot. Formal interviews prepare you for the technical questions companies will ask you when applying for a job after your degree.

It puts the thoeory of other modules into practice and allowed us to aprciate it more. It also helped me to learn certain concepts that were brought up in PBL that helped in learning them later on, such as op amps for example.
The team work alone is what is key to success. Companies are always interested in your project/team work.
All apply. I will not consider myself an exam person but rather, a much better learner through the solving of real-world problems.
Honestly I feel all characteristics helped me achieve success in my engineering programme. This might seem like a cop out answer, but I felt like PBL 'rounded' my skillset. This let me be very adaptable over the course of my degree, and navigate my way around problems, rather than being stumped by them.
PBL is probably the most useful and important part of my degree in aiding my understanding for how things I have learned in theory practically work. Realistically, the majority of what I learn I don't actually understand until its applied to something im actually doing, which is counter intuitive as its normally after I do my exams that the information is used. So I could learn something, do an exam based on it and not really understand it until months later.
I would most attribute the skills from PBL that I wouldn't learn while sitting in a lecture to my success in the programme. Skills like communication, team management, work organisation and planning are necessary to succeed in any career and PBL has allowed me to put these into practise in a relatively stress free environment in conjunction with my course work, which I've found very helpful while on IWE.
Learning the importance of creating an actionable plan with regular deadlines/timeframes, understanding the benefits of consistent work over rushing all work towards the end of the project. Knowing the importance of being a team player.
The aspect of working in teams which enhanced my knowledge of the topic in research and the subject in question and helped give me a better understanding of the subject at times because it was coming from a friend or a person who I could relate to easily.

Aalborg University Masters Students with experience of PBL

Q1. Please indicate (√) on a scale of 1 (not so important) to 5 (very important) how important the following indicators of success are for you:

	Not so Important 1	2	3	4	Very Important 5
Graduating with first class honours	1/8	1/8	4/8	1/8	
Graduating with at least a 2.1 honours			2/8	3/8	2/8
Just passing my exams and graduating	2	2	2	0/8	1/8
Developing my teamwork skills				2	6
Developing my presentation skills			2	1/8	5/8
Developing my report writing skills			1/8	4/8	3/8
Developing my project management skills			2/8	1/8	5/8
Being able to apply my theoretical knowledge to solve real-world problems					8/8

Q2. Describe briefly what the acronym 'PBL' means to you.

The acronym PBL, Problem Based Learning, has been a great discovery for me, because it encourages you to take part into the education process in a complete different way as in most tertiary education institutions. It is a challenging way of facing knowledge, and instead of the only technique of acquiring new information, it includes as well constant reflection and searching of more information to complement the lectures at university. Therefore, according to this model of learning, the individual put in practise all the knowledge acquired and face real problems, always in collaboration with his or her teammates, so the learning process is both an individual and a group activity.
When I think of PBL the first thing that comes to mind is 'structure'. I am from Bulgaria and we have a different educational system. The one sided type- teacher comes in, presents the information and leaves. I've experiences this PBL for the first time I came to Denmark. It teaches you to think on your own, to search for information on you own from various sources, to discuss what you found and to be able to defend your decisions. It teaches you to question information. It teaches you how to work in a group and in a healthy environment. PBL teaches you how to recognize and handle a certain subject or a project in the best way. In my opinion it is very useful and is the best way to study. The best think is you have to deal with a lot of problems from different spheres. That in real life is the most important thing.
Human resources and administration
Problem Based Learning for me means that I don't focus only on the subject itself only but try to solve it in a team by applying different solutions, being open-minded.
For me ´PBL´ means group work. Where you work in a groups to find solution to problems.

It is a summation of, collaboration, presentation, and an understanding of how peop **But especially how to cooperate with others.**
I believe communication skill will be improved for solving conflicts and misunderstandings
The biggest parts of PBL for me are the projects, and problems, set in real life and the group work. These two together make the learning part much more enjoyable and challenging whilst also being very similar to how you would work in a real life situation.

Q3. What in your opinion/experience are the main characteristics of PBL?

Problem based learning is described as an active learning process, where the student doesn't only attend the lectures to obtain information, but also develops activities both individually and in group, like the project report (which is the most important task of the semester). The process is continuous in time, so it demands full time of the individual, and thank to PBL I was able to discover my approach to knowledge, which are my learning techniques, and most important, which are the techniques used by the other members of my group, so it was an enriching experience so far. Also this educational model allow us to face the possible problems and situations we will have to deal with in our professional careers, and our capabilities to perform and upload the work in a continuous way are also put in practice. So it is very valuable to receive feedback from our teammates and from our teachers. Other important aspect to mention is the close collaboration we have with most of the lecturers, a situation which is not that common in other educational methods, I can assure. Finally, PBL force the students to work collectively, so the possible free riders are taken out of the system sooner or later. This means that the student has to make agreements with his or her colleagues, and they will irremediably face at some points tough situations to overpass, because sometimes the visions or perceptions will be different or even opposite, and it is a responsibility of the students to success in these situations, allowing them to be fully prepared for real life and acquiring problem-solving abilities.
I think I answered in the previous question (see Q2 response 2 above)
Learning about yourself and how and why you do what you do. Then learning about each other. Administration, team building, meetings, reflecting. Organising documents for general office function in regards to an office consisting of more than one person.
Teamwork, thinking out of the box, being innovative
I find that PBL biggest experience is solving conflicts between group members.
Cooperation. **Respect other people's differences.** **Resolution of conflicts**
Communication. Body language. And writing skills
For this 1. semester having to deal with some problems in our group has teached me a lot about team work and how it is to learn in a group. When problems arise, you have to be ready to tackle the problems in a precise but fair manner.

Q4. What characteristics (if any) of PBL do you attribute to your success in your engineering programme?

The characteristics performed during this first semester of my education thank to PBL module where many, but I will personally insist in the capability to work in group and to have a close collaboration with my colleagues. Using some of the tools described in the lectures, and because of our constant checking of the tasks made during the semester, I feel more confident in work in an international team, discussing ideas and trying to reach a common vision when we have different perspectives. It was really enriching to learn with them, and to discover how productive was to share this continuous learning process with people with completely different cultural backgrounds and perspectives. Also the project management and time-planning techniques that I have been using during the earlier years of my education were implemented, and certain comments from the lectures of the module were taken in consideration when we made our brief planning for the project work. Soft and hard-deadlines were used during all these weeks. And finally, and probably the most notorious point to mention, is that PBL course was a really helpful tool to approach more in depth to the educational model present in Aalborg University, facilitating my early adaptation, as well as receiving complementary education apart from my engineering modules. It allowed me to make a self-reflection of any task that I face or that I will face in the next semesters of my education and in my future professional career, to obtain the global understanding of a certain situation, and to put in practice all the knowledge acquired to give a solution for that situation. So I will conclude that PBL should be considered in every kind of tertiary education, no matter what field of knowledge are we considering, and of course it MUST be in the engineering programmes, because it will be an extremely valuable tool for the students to complement their education and perform their learning techniques and work methods.
I gained knowledge how project work goes. Learned to distinguish the different types of projects and how to proceed with the work, so I am productive. It is complex and is made of a lot of small characteristics that, when you put together are very helpful.
Keeps us organised in the daily running of a group and insures we set some common goals and communication early so that we can produce a good project and function well together.
Learn how to work in a team helped to achieve higher results, responsibility for the team not only for myself will help me in my future career.
My biggest success throw PBL learning is that I have improved my presentation skills from shaking in front of an audience to be able to talk with confident.
Having learned to work with other people, and learned to accept others and their different wa world. In addition, have learned to stay calm in conflict resolution as well
Learning the different personalities and communication, one of my skills is coordinating the team. And closing a project.
Definitely team work with peer 2 peer teaching and knowledge sharing playing a big part. Besides having so much work to do, we all have different skill levels for the different tasks. So not only is there a need to thrust all group mates to deliver on their tasks but also to learn and share from your knowledge and also to learn from your group mates.

Questionnaire Responses from Chinese students taking year 4 of the BE(Eng)

Q1. Please indicate (√) on a scale of 1 (not so important) to 5 (very important) how important the following indicators of success are for you:

	Not so Important 1	2	3	4	Very Important 5
Graduating with first class honours	1/6	1/6	1/6	2/6	1/6
Graduating with at least a 2.1 honours	0/6	0/6	1/6	0/6	4/6
Just passing my exams and graduating	2/6	1/6	1/6	1/6	1/6
Developing my teamwork skills	0/6	0/6	0/6	5/6	1/6
Developing my presentation skills	0/6	0/6	2/6	3/6	1/6
Developing my report writing skills	0/6	0/6	1/6	3/6	2/6
Developing my project management skills	0/6	0/6	1/6	3/6	2/6
Being able to apply my theoretical knowledge to solve real-world problems	0/6	0/6	1/6	1/6	4/6

Q2. Describe briefly what the acronym 'PBL' means to you.

Logical thinking and engineering building ability.
It means students themselves should gain the ability to study by themselves, when they get problems they go to the lecturer to discuss how to solve it. It's more about self-learning and lecture is not so important as the traditional study method.
PBL means problem based learning, in my opinion, everything is based on problems. Where there is a problem, I need to solve that, so that is a procedure for learning.
I think PBL is Programme Based Learning. It represents what i gain from doing a programme.
PBL can help me learn knowledge more clearly and carefully, and understand it.
PBL is Project Based learning to me, It is a way to learn about a subject through the experience of solving problems.

Q3. What in your opinion/experience are the main characteristics of PBL?

Help to solve problems in real world.

High efficiency. Because you know what's your question is and want to solve it directly. Traditional study may waste some time because when you come to one lecture you may find the knowledge told by lecture you may have already studied.
Notice the problem by myself More personal customized. Everyone has different needs for learning
Programme based learning can improve learning skills by using theory in true event.
The main characteristic is interaction between student and teacher.
The main characteristics of PBL is based on the problems from project, students research the related knowledge and have their own design to fix the problems. There are lots of ways to solve the problems and finish the project.

Q4. What characteristics (if any) of PBL do you attribute to your success in your engineering programme?

Project management.
Flexible. For example FYP is one kind of PBL. No lecture is given for this project. I just find related information to my project on the internet and do research by myself. And I sort out the questions then go to ask my supervisor. Self-learning may also spend a lot of time but it is more impressive to me comparing to lecture mode.
Customized for different needs for learning. I will be more willing to explore what I do not know and it seems to be attractive.
Programme based learning always means programme based unknown skills. This keeps my enthusiasm in studying new things.
-
In my engineering programme, the main characteristics of a successful Project-Based Learning is to describe the problem firstly. Then design the work with detail in the project. Last but not least is system testing, after design.

Questionnaire Responses from year 2 (completed) students of Engineering Science

Q1. Please indicate (√) on a scale of 1 (not so important) to 5 (very important) how important the following indicators of success are for you:

	Not so Important 1	2	3	4	Very Important 5
Graduating with first class honours	0/3	0/3	1/3	1/3	1/3
Graduating with at least a 2.1 honours	0/3	0/3	0/3	1/3	2/3
Just passing my exams and graduating	1/3	1/3	1/3	0/3	0/3
Developing my teamwork skills	0/3	0/3	0/3	2/3	1/3
Developing my presentation skills	0/3	0/3	0/3	2/3	1/3
Developing my report writing skills	0/3	0/3	2/3	0/3	1/3
Developing my project management skills	0/3	0/3	0/3	1/3	2/3
Being able to apply my theoretical knowledge to solve real-world problems	0/3	0/3	0/3	0/3	3/3

Q2. Describe briefly what the acronym 'PBL' means to you.

To tackle what might seem like a larger and more difficult problem using a team of people. The individuals are better able to break the problem down and work through it together.
To me, project based learning is about trying to apply theory from the course in the real world, and benefitting from the experience of solving the problems that arise.
For me it means to learn from mistakes that I made throughout the PBL module. It also means that I can learn new skills with my team to overcome a problem and find a solution.

Q3. What in your opinion/experience are the main characteristics of PBL?

Teamwork Problem Solving Report Writing/Presentations of findings Time and team management
I had a great experience of PBL, with a very sociable group, capable of communicating what we wanted to do personally and, for the most part, pooling our knowledge into solving the troubles that arose. What made it particularly good, was the small group size, making it very easy to organise meetings!

The first main characteristic is the teamwork and communicative skills. Because without them it would be really difficult to accomplish something in a group. By practical work in the lab you can learn a lot more from that rather than just reading notes online and trying to understand how will that work in reality.

Q4. What characteristics (if any) of PBL do you attribute to your success in your engineering programme?

Better able to take the theoretical knowledge learnt in lectures and apply it to a real world type situation. Communication skills were also developed which allowed me to better portray my ideas and thoughts when asking questions and explaining myself.
-
I can say that my teamwork, communicative presentation and report writing skills improved a lot and which I think will be very helpful in future jobs! In my opinion this is a great Programme and I would advise everyone to do it and learn from it because it'll guarantee you skills that you would not acquire by just going in to the lectures!

Questionnaire Responses from 2nd year (completed) Engineering students

Q1. Please indicate (√) on a scale of 1 (not so important) to 5 (very important) how important the following indicators of success are for you:

	Not so Important 1	2	3	4	Very Important 5
Graduating with first class honours	1/2	0/2	0/2	1/2	0/2
Graduating with at least a 2.1 honours	1/2	0/2	0/2	1/2	0/2
Just passing my exams and graduating	0/2	0/2	0/2	0/2	2/2
Developing my teamwork skills	0/2	0/2	0/2	2/2	0/2
Developing my presentation skills	0/2	1/2	0/2	1/2	0/2
Developing my report writing skills	0/2	0/2	0/2	2/2	0/2
Developing my project management skills	0/2	0/2	1/2	1/2	0/2
Being able to apply my theoretical knowledge to solve real-world problems	0/2	0/2	0/2	0/2	2/2

Q2. Describe briefly what the acronym 'PBL' means to you.

Working on a problem in theory and solving it in a practical manner.
It's a team project thing

Q3. What in your opinion/experience are the main characteristics of PBL?

Understanding the problem and coming up with ways to solve it. Utilising all resources as possible. If in a team, working together so that everyone gains some insight or skills by the end of the project.
Doing more practical stuff and building things

Q4. What characteristics (if any) of PBL do you attribute to your success in your engineering programme?

-
Applying things you learn to real world problems

EE299 Project-Based Learning (PBL) – Survey

18th May 2016

1. Project Based Learning (PBL) overall

Instruction – place an 'X' in the appropriate box for each of the statements listed below.	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
PBL is an effective method of learning for me.	5/14	7/14	2/14		
PBL prepares me for my exams.		4/14	3/14	7/14	
PBL prepares me for my future professional life.	7/14	5/14	2/14		
PBL improves my teamwork skills.	8/14	6/14			
PBL improves my written communication skills.	4/14	8/14	2/14		
PBL improves my presentation skills.	10/14	3/14		1/14	
PBL has motivated me to learn.	5/14	9/14			

1.1 How would you describe the concept of PBL?

Allowing a group of individuals to control their own learning is an interesting way to see how people work outside of a "spoon-feeding" environment. By doing this it becomes clear very quickly how members would react in the workplace, and see who haven't reached that level yet.
It was a way to improve our teamwork, professional and communication skills
Using what we learned to find solutions to real world problems
I feel that it was a chance to get us ready for the type of work we were getting into in terms of understanding the problem and having the ability to solve it.
It allows a person to delve into a problem and evaluate said problem from every aspect to solve it.
Leaning through doing.
Leaning through practical work and research.
Project work to improve teamwork skills and independent learning.
Create a group project based on a design problem given to us. Applying things we learned throughout the course and use research skills.
It's a very good idea because having only theory modules would be not good.
-

It’s a good concept that allows us to enhance our problem solving skills and teamwork skills.
I would describe PBL as a practical and far more effective method of learning what we cover in lectures.
PBL is a module of a large project split into smaller tasks over a semester.

1.2 Why do you think we use PBL?

To simulate the workplace environment, give a taste for the freedom that comes with directly working with colleagues and the structural skill to see it through.
To get you ready for the real world.
To prepare us for a real world engineering job etc.
As an engineer we must be able to understand and be capable to solve problems given. That is why I feel the name PBL suits its description.
I think we use PBL to give people an insight of how it will be to work in an establishment. It gives people an idea of how work is done in a work place.
So we can learn how to work by yourself.
To take a different approach to learning.
To help prepare us for group work in the workplace.
To promote creative thinking and prepare for future work in engineering. To promote teamwork and initiative.
Its nice to do practical things.
To prepare students for the working world.
To see how we work without a process given to us.
To help improve our problem solving and critical thinking skills. Also, to practically apply what we learn.
PBL is used to promote teamwork, planning, group communication and organisation.

1.3 What part of PBL worked well, and why?

For us we had very different members all with different skills and personalities that worked constructively rather than destructively. As our project teams we not our own choice, this was the luck of the draw.
Teamwork skills
I enjoyed writing up the reports and learning about the content. This worked well because I learned more than I would have through the other modules alone.
The part that worked well was the team allocation to which work could be divided.

The members of the group were comfortable with each other thus there were no conflicts and work was constantly and consistently done.
Interesting topics.
Having to research how to do a specific problem and solve it.
The teamwork aspect went well, everyone was co-operative.
Learned new things wouldn't have in lectures. Design and constructing the project.
Applying the theory we learned to practical application.
The fact that we work in teams rather than alone. The work is not all on one person then.
Teamwork allowed people to explain parts others didn't understand.
The teamwork and learning from one another. I find it far easier to learn when someone physically shows me how something works than explains why.
The promotion of teamwork worked well as by the end of the semester the group could work together as a unit.

1.4 What part of PBL did **not** work well, and why?

Time restraint was a problem but more so other responsibilities were. Near the last few weeks of this semester all members worked tirelessly between project reports and revision for all other modules. The workload caused a huge lack of preparation for project presentation & interviews.
Having exam on other modules
Sometimes there's conflict between members and also, it was hard to balance the workload between PBL and other modules.
In our case, the building of the product which we attempted but were unable to create a signal which we could interpret. This was due to time constraints.
PBL was not an issue but the workload was overwhelming. It was difficult to juggle PBL and all the other modules at the same time.
How due dates meshed with other modules due dates.
Scheduling time aside for PBL.
Time scheduling was difficult. Not enough time was given to debugging the final device.
The business proposal did not go well for our team. Did not understand fully what it was. Focus more on technical than business did not get final project to work completely.
I didn't see much of a point in the business part honestly.
The time frame for the project. But not a lot can be done about that.
For me it was the presentation and interview as I get too nervous and then mess up what I know.

The time constraints, due to weekly assignments and the academic exams it was very difficult to find time to put towards PBL. To put enough time in to achieve what was needed.
As the project was over one semester, I felt as if the allocation of time was insufficient leading to us having ideas unused.

Questionnaire Responses from year 1 (completed) Product Design students with experience of PBL

Q1. Please indicate (√) on a scale of 1 (not so important) to 5 (very important) how important the following indicators of success are for you:

	Not so Important 1	2	3	4	Very Important 5
Graduating with first class honours			1/9	4/9	4/9
Graduating with at least a 2.1 honours				4/9	5/9
Just passing my exams and graduating		1/9	2/9	1/9	3/9
Developing my teamwork skills			1/9	5/9	3/9
Developing my presentation skills				6/9	3/9
Developing my report writing skills		1/9		5/9	3/9
Developing my project management skills				3/9	6/9
Being able to apply my theoretical knowledge to solve real-world problems				1/9	8/9

Q2. Describe briefly what the acronym 'PBL' means to you.

PBL: Problem Based Learning. Its good preparation for what id assume is the real world work environment.
PBL means problem based learning which to me is solving problems.
Helps to develop learning skills that can be applied to real life situations
To me the acronym 'PBL' means Problem Based Learning. Problem based learning is where a person is tasked with a project or problem and then they must figure out how to solve this. It is an alternative method of learning, rather than being lectured on the subject and then doing a written exam based on theory taught in lectures.
Being given a problem or a challenge and being able to use the resources available to you to solve it.
Learning about a subject through solving an open-ended problem
It helps us understand how to attack problems in the right way to make it easyer to do product design
PBL to me is an opportunity to work with others and collaborate your ideas and set a goal to reach at the end of the semester. To me it means furthering your knowledge by taking constructive criticism from others in your group and also in return so everyone can move forward. Spending a substantial amount of time on a project means you study it further in depth and strengthen your knowledge on critical and sometimes a limited amount of information which is involved specifically for your project.
PBL (problem solving learning) is a way of bringing people together to solve a problem that will benefit their learning experience.

Q3. What in your opinion/experience are the main characteristics of PBL?

Learning at your own, or group's pace. More rewarding in outcomes as the grade you get is determined but the amount of work you put in, unlike strictly written exams that you can often study for the night before.
Being able to adopt and adapt as things change keeping an open mind is very important.
-
In my opinion the main characteristics of PBL are hard work, communication and persistence.
PBL requires a want to learn, if you are not interested in learning you aren't going to learn because you are not going to put the work in. Having something that you are interested in working on. That it is ok to get things wrong. That you evaluate everything and keep a record of what you have done be it right or wrong.
Solving the problem wouldn't be the key experience I think the most important things are figuring out ways to solve the problem through unique methods and also being able to compromise and work with a team.
No comment
I think PBL is a good way to learn new concepts although it could be limiting you to what you could learn in a semester if you are only focusing on one task. Working in a team is very useful as you get a broader range of ideas but this doesn't always work if not all members are interested or willing to work. I think PBL is useful as you feel a sense of achievement after it especially if you reach your target goals and sometimes you subconsciously don't realise you are learning as much as you are.
PBL characteristics would be: Teamwork Leadership communication

Q4. What characteristics (if any) of PBL do you attribute to your success in your engineering programme?

Not being limited to what the whole class is capable of. Stronger students and weaker students are both equally facilitated in their tasks and are thusly rewarded for the relative difficulty they underwent to succeed in those tasks.
I believe I am a good thinking and I think outside the box, this is very useful for PBL.
-
I find that all of the characteristics which I mentioned above have contributed to my groups success in our engineering programme. We communicated well, worked hard and were extremely persistent. We were not success in completing our project, however, I feel that through hard work and persistence we still managed to do a satisfactory project.
I think that having a project, that as a group we were all interested in and something that we could relate to was a big factor in the success of this programme.
Most of my success because it allowed me to explore my creativity and being able to learn with my peers without being in a controlled environment.
No comment
I think reaching our target goal was a big success and also from very useful guidance from our mentor we learnt a lot in our engineering programme through the course of the uni year. I feel the one thing that could be improved is making the groups smaller and that way it is easier to move forward with the project and also ensure each team member is playing their part. I think,

especially for myself, considering I had no knowledge about engineering before September, collaborate work was very useful as other helped me to understand the basics.
Leadership, good communication amunst the group we always kept in contact through a groupchat. Teamwork as we always agreed on an idea and made it happen.

Appendix 2 – Focus Group Transcription

What characteristics (if any) of PBL do successful students attribute to their success on an Engineering Programme?

1 Based on your PBL experience what makes a PBL group succeed in achieving their project goal?

A. Yes, self oriented learning and group oriented learning ,when students go off and learn on their own and then help from team mates as well.

Self directed learning helps, anything else you thought helps?

Everyone always wants to do well

Do you think that's different in a group than individually

No one wants to drag the group standard down

It involves real problems, as engineers we enjoy building things, we don't like learning theory all the time, so we can implement what we learn and do practical stuff

It's much more difficult individually as there's much less resources for that kind of thing

A good deal of documentation as so many people can record results.

The nature of the documentation? What tools can you use? What elements are used?

The project planning and internal reports

Is there informal documentation?

When we hold meetings, we have minutes so everyone can look them over in case they have missed anything

What communication tools did you use there? Did you e-mail each other, did you text each other, did you have a forum space?

Facebook!

Did you set up a page?

We set up a group and we could share all the stuff

Is there something about it being private for you that makes it different?

It removes the shyness factor, so lecturers can't see it, and only the group see it

It's more convenient for us – we'd be on Facebook anyway.

So you're really comfortable using it as a tool?

Communication is a little faster than Moodle or e-mail, instead of waiting, it pops up instantly, and live. Most students won't have Moodle open 24/7.

Is always on your phone?

Yes, we get notifications instantly, automatically

If you got some of that for your project, would you look at it?

Absolutely, because you want to know what it is

Do you think the speed at which you can access it transpires into the response?

Yes, if it's related to group work

So if it was on Moodle you wouldn't be inclined to look at it as quickly

If I post for the group today, I expect that everyone will see it by tomorrow, because I know everyone's on Facebook everyday

Based on your PBL experience, what makes a PBL group NOT succeed in the project?

If there's someone in the group postponing or procrastinating or being lazy saying we have plenty of time, that might prevent us from achieving our goals

If my part is depending on someone's research, that causes a domino effect

You're only as fast as your slowest group member.

When that breaks down what happens?

?????????????????? Cant' hear what she's saying and her diction is awful !!!

There's a cause and effect. If one of the team doesn't do the work, if might give me justification to not go at my original pace, so you're not really in a position to criticise me, if you're not pulling your weight. There is a shift when that comes into place. People don't feel as obligated to work.

From past experience, if there's disagreement of how the elements should be executed, or what should be included, someone might say I don't want that in my project that can cause disagreements, ***……..?????????????????***

Any other reasons?

Yes, where you can have an excessive numbers of people in the group that can really determine whether the work gets done, or how well the group works together

What do you think is the best number

I think 4 or 5

Any comment on gender split

No it doesn't matter

A friend of mine works in a group and she is always given the research or typing. You're supposed to be helping each other and all doing the work, but she's not getting to understand the technical part…..i think the group could be more supportive instead of ***(again can't hear a lot of what this girl is saying?)***

I think it's up to the person, to learn more, and to …………..there's no point in me going to write the report if I don't know how to write a report ***(Can't hear a lot of this)***

So if there's an assessment involved, you're better to let people play to their strengths, rather than to say you've learnt it all…..

When students form a group and they speculate on how it might go, they base it on the academic strengths of their team mates, and never really on gender or religion or background or whatever. It's purely as how they see you do.

Anything else?

If there's even one person not good on time management or there's more people, communication doesn't function as well, and when there's bigger numbers some students they don't feel there's a need to take it as seriously

If a PBL group is not working well together, what can be done to improve things?
have you encountered it and what did you do?

We would probably have a meeting,

You're trying to be nice about it, but sometimes you get angry!

Does someone eventually have to say something, is that upfront

Yes, it's pretty much up front!

Any other ways where those problems are addressed?

I think the best way is to split the group and say we're done. Then the people who aren't doing the work are left.

Would you have done that?

Yes, in theory, you can have the facilitator to mediate in it,

Would you go to the facilitator?

Well it's really up to us, to fix it ourselves

Can't hear / decipher the female's comments here

If you decide splitting is not an option, what can you do to improve the work rate/productivity?

Maybe elect the person who doesn't have a disagreement to distribute the work.

Can't hear / decipher the female's comments here

Do you have guidelines/terms of reference for hitting deadlines etc?

More informal agreement, more implicit in the group

Would it help if you were explicit?

That can put a structure on the group – about the time you meet each week and what work should be done and hope progress is made by the time the next meeting comes around

We have a bit of structure, to decide on deadlines, but we're always rushing to finish projects and assignments.

Based on your PBL experience how did the individual personalities in the group influence the overall success or failure of the project?

I think it's quite heavy, how personality of each individual. It's based on how any two people might get along. If there are two people who already have an attitude with each other, then that's going to carry in to the group.

It can happen that if there's a difference between someone who takes on all the work and someone who doesn't want to do any work at all, conflicts can come in.

What else impacts on the group?

It's always good to have someone as a Leader as well. If you have a group of people who don't know what direction they're going in, there's usually one who acts as the leader.

The person who takes over as the chairperson/leader could lead to the group building up a ball of anger ……….. ***Can't hear / decipher the female's comments here….very difficult to hear it.***

Are there any other last comments you want to make on the PBL experience?

Would you do anything differently or what you particularly liked?

I think PBL should be a group work that's based on people who actually are comfortable around each other, then you can get your work or your project done. There might be arguments but it's easier than new groups.

Individual attendance makes a statement of its own, if you attend most of them, you're indicating that you're interested in getting the work done, if you don't attend regularly it indicates that you don't have an interest in the project.

Would you rather work face to face or on line?

Face to face is much better

All agree

Appendix 3 – PBL Module Descriptors

Module Name **Module Code** **Version** **Last Reviewed**	Electronic Circuits Project (Project Based Learning Pilot) EE199 2012–2013a 18th Jan. 2013
Module Co-ordinator **Department**	Refer to Excel document *Module_Co-ordinators* Electronic Engineering
Module Level **Credit rating**	1 10 ECTS credits
Pre-requisites	EE101 Electronic Engineering Fundamentals, EE103 Computer Architecture and Digital Logic
Co-requisites	EE111 Electric Circuits, EE112 Engineering Mathematics 2

Aims	• To introduce project based learning. • To introduce students to structured engineering design. • To instill the creative spirit in students. • To develop oral and written communication skills • To develop students experience of working in a group • To engender an awareness of ethical issues in engineering
Learning Outcomes	At the end of this module a student should be able to: 1. Apply project-based learning to solve unforeseen problems. 2. Apply structured design to a range of problems. 3. Apply theoretical knowledge in solving problems encountered. 4. List basic ethical requirements in engineering. 5. Write a technical report. 6. Prepare and deliver an oral presentation. 7. Defend their work through interview. 8. Demonstrate appropriate management techniques in the execution of their project (including time management and project planning)

Time Allowance for Constituent Elements	
Workshops Independent study (including meetings, reporting, etc.)	15 hours 235 hours

Workshop Content
Workshop 1 – Project-based learning & Group work Workshop 2 – Engineering design fundamentals Workshop 3 – Engineering ethics Workshop 4 – Technical report writing Workshop 5 – Presentation skills

Assessment Criteria	
Interim Report (R) + Presentation (P) + Interview (I)* *R: Presentation / Structure / Communication (15%)* *R+I: Introduction / background (20%)* *R+I: Progress to date (40%)* *R+I: Work plan / Gantt chart (15%)* *P+I: Overall competence / professionalism (10%)*	20%
Final Report (R) + Presentation(P) + Interview (I)* *R: Presentation/Structure/Communication (15%)* *R+I: Understanding of problem domain (20%)* *R+I: Methodology (15%)* *R+I: Technical content – quantity and depth (40%)* *P+I: Overall competence/professionalism (10%)*	70%
Reflective Journal (to include individual and group reflection) *One report is submitted per group. However, each member of the group will be graded individually. Their grade will be based on the group report and presentation, their individual contribution to the project and, significantly, their knowledge of the overall project, as determined by the interview.	10%

Penalties: Late submission of reports will be subject to a penalty of 10% of the assessment grade for each day (or part thereof) overdue.

Pass Standard and any Special Requirements for Passing Modules: Pass 40% - students are not required to pass components separately – an overall pass mark of 40% is acceptable.

Repeating: This course is 100% continually assessed. Hence, there is no repeat Autumn examination. Projects can only be repeated by repeating the year and students will be required to undertake a new project.

Continual Assessment Results: Reports will be corrected within two weeks, provided that this does not extend past the end of the semester. Results and corrected scripts will be available for viewing upon request.

Assessment Philosophy

The different modes of assessment employed (reports, presentation and interviews) evaluate learning outcomes 5 – 7. Learning outcomes 1 – 4 are primarily evaluated in the final report and interview. The number and scheduling of the assessment procedures are designed to indirectly evaluate learning outcome 8. Direct assessment of learning outcome 8 also occurs in the interim report through the requirement for a project completion plan and Gantt chart.
Programmes currently utilising module
BE in Electronic Engineering BE in Electronic Engineering with Computers BE in Electronic Engineering with Communications

Module Name **Module Code** **Version** **Last Reviewed**	Analogue Electronics Project (Problem Based Learning) EE299 2015-2016 26th Jan. 2016
Module Co-ordinator **Department**	Refer to Excel document *Module_Co-ordinators* Electronic Engineering
Module Level **Credit rating**	2 10 ECTS credits
Pre-requisites	EE204 Analogue Electronics, EE199 Project (PBL)
Co-requisites	None

Aims	• To promote project based learning in the field of analogue electronics. • To instill the creative spirit in students. • To develop oral and written communication skills. • To develop students experience of working in a group. • To engender an awareness of ethical issues in engineering. • To develop a basic business proposal.
Learning Outcomes	At the end of this module a student should be able to: 9. Apply problem-based learning to solve unforeseen problems in the area of analogue electronics. 10. Apply structured design to a range of problems. 11. Apply theoretical knowledge in solving problems encountered. 12. Apply a structured process to business proposal research, including market research, user research and competitor analysis. 13. Prepare a set of manufacturing documentation (costed BOMs, Assembly and Test specifications). 14. Discuss any ethical issues, environmental impacts and health and safety issues associated with their project. 15. Write a product concept report (including technical and business feasibility issues) and prepare and deliver an oral presentation. 16. Defend their work through interview. 17. Demonstrate appropriate project management techniques (including time management and project planning).

Time Allowance for Constituent Elements	
Workshops Independent study (including meetings, reporting, etc.)	12 hours 238 hours

Workshop Content
Workshop 1 – Problem-based learning – revision & reflection Workshop 2 – Project Planning Workshop 3 – New product development – market and user research Workshop 4 – The new product business proposal

Assessment Criteria	
Business Proposal – Report, Presentation and Interview*	20%
Final Report + Interview* *Presentation/Structure/Communication (15%)* *Understanding of problem domain (20%)* *Business proposal (15%)* *Technical content – quantity and depth (40%)* *Ethical considerations (10%)*	60%
Final Presentation	10%
Project Management Report *(including project plan and Gantt Chart)**	10%
*One report is submitted per group. However, each member of the group will be graded individually. Their grade will be based on the group report and presentation, their individual contribution to the project and, significantly, their knowledge of the overall project, as determined by the interview.	

Penalties: Late submission of reports will be subject to a penalty of 10% of the assessment grade for each day (or part thereof) overdue.

Pass Standard and any Special Requirements for Passing Modules: Pass 40% - students are not required to pass components separately – an overall pass mark of 40% is acceptable.

Repeating: This course is 100% continually assessed. Hence, there is no repeat Autumn examination. Projects can only be repeated by repeating the year and students will be required to undertake a new project.

Continual Assessment Results: Reports will be corrected within two weeks, provided that this does not extend past the end of the semester. Results and corrected scripts will be available for viewing upon request.

Assessment Philosophy
The different modes of assessment employed (reports, presentation and interviews) evaluate learning outcomes 7 and 8. Learning outcomes 1 – 6 are primarily evaluated in the main report and interview. The number and scheduling of the assessment procedures are designed to indirectly evaluate learning outcome 9. Direct assessment of learning outcome 9 also occurs in the

project management report through the requirement for a project completion plan and Gantt chart.

Programmes currently utilising module
BE in Electronic Engineering BE in Electronic Engineering with Computers BE in Electronic Engineering with Communications

Module Name **Module Code** **Version** **Last Reviewed**	Signals & Systems EE301 2014–2015 19th Sept 2014
Module Co-ordinator **Department**	Refer to Excel document *Module_Co-ordinators* Electronic Engineering
Module Level **Credit rating**	3 5 ECTS credits
Pre-requisites	EE106 Engineering Mathematics 1, EE112 Engineering Mathematics 2, EE206 Differential Equations and Transform Methods, EE212 Complex Analysis and Vector Calculus
Co-requisites	None

Aims	• To give a detailed introduction to signal analysis techniques. • To develop from first principles the theory for the analysis and design of discrete-time signals and systems.
Learning Outcomes	At the end of the modules, students will be able to: 1. Represent and analyse signals in the time and frequency domains. 2. Represent and analyse linear, time-invariant systems in the time and frequency domains. 3. Perform continuous-time and discrete-time convolution of signals. 4. Compute the continuous-time and discrete-time Fourier transform of signals and systems. 5. Explain the fundamentals of sampling theory, alias and repeat spectra. 6. Compute the Z-transform of discrete-time signals and systems. 7. Compute the discrete Fourier transform of discrete-time signals and systems. 8. Determine the frequency-response of a system using a white noise input. 9. Compute the periodgram of a signal. 10. Analyse the frequency content of a signal using Bartlett's method. 11. Work as part of a team.

Time Allowance for Constituent Elements	
Lectures	12 hours

Tutorials Project Independent study & online interaction Semester Examination	12 hours 40 hours 59 hours 2 hours

Indicative Syllabus

- Introduction:
  Signals, Systems, Linear Systems, Time-Invariant Systems, Continuous-time signals and systems, Discrete-time signals and systems, Fourier Series representation of signals and systems.
- Continuous-time signals and systems:
  The impulse function, properties of the impulse function, Fourier transform of the impulse function, impulse response and frequency response of continuous-time systems, convolution, the sifting integral, the Laplace transform, pole-zero models.
- Discrete-time signals and systems:
  Sampling, uniform and non-uniform quantization, Linear difference equations, frequency response of discrete-time systems, discrete-time convolution and unit sample response, sampled bandpass signals. Intro to digital filters.
- The Z-transform:
  Convergence of the ZT, properties of the ZT, Applications of the ZT.
- The Fourier transform (FT):
  The discrete-time FT (DTFT), properties of the DTFT, Parseval's Theorem, Sampled signal spectrum, Repeat spectra, Alias, Periodogram.
- Random Signals:
  Types of noise, Frequency-response estimation using noise. Random variables, Probability Density Function (PDF), Random processes. Spectral estimation. The periodogram. Bartlett's method.

Assessment Criteria

Semester Examination Continuous Assessment: Individual logbooks (15%) Group project report (15%) Individual Project Interviews (20%)	50% 50%

Penalties: Continuous assessments components cannot be repeated, in general. Late submission of reports will be subject to a penalty of 10% of the assessment grade for each day (or part thereof) overdue.

Pass Standard and any Special Requirements for Passing Modules:
In order to pass this module, students must achieve at least 30% in both the final exam and the combined continuous assessment components separately, and an overall mark of at least 40%.

Requirements for Autumn Supplemental Examination: The continuous assessment mark is carried forward to the Autumn examinations as there is no facility available for repeating the continuous assessment components of the module.

Continual Assessment Results: Continuous assessment components will be corrected within two weeks. Results and corrected scripts will be available for viewing upon request.

Assessment Philosophy
The group project provides an opportunity for the students to work as part of a team (see learning outcome 14) on a signals and systems project of their choice. A typical project will include learning outcomes 1 thru 5 inclusive plus some of the other learning outcomes. Each student is required to maintain an individual project logbook which will be used during the project interviews. The end-of-semester examination is designed to assess learning outcomes 1-13 and accounts for 50% of the overall marks.

Course Text	Simon Haykin and Barry Van Veen, Signals and Systems, 2nd Edition. Wiley Publications. ISBN: 0471164747
Reference	Signal and Systems, Models and Behaviour, 2nd Edition. M.L. Meade and C.R. Dillon, Kluwer Academic Press.

Programmes currently utilising module
BE in Electronic Engineering BE in Electronic Engineering with Computers BE in Electronic Engineering with Communications

Module Name **Module Code** **Version**	Digital Signal Processing EE401 2015
Module Co-ordinator **Department**	Refer to Excel document *Module_Co-ordinators* Electronic Engineering
Module Level **Credit rating**	4 5 ECTS credits
Pre-requisites **Co-requisites**	EE301 Signals & Systems None

Aims	• To give a detailed overview of the theory of DSP • To give a detailed overview of the application of DSP to selected areas in electronic, computer and telecommunications engineering
Learning Outcomes	At the end of the modules, students will be able to 1. Compute the fast convolution and fast correlation of two discrete-time sequences 2. Compute the Short-Time Fourier Transform (STFT) of a sampled signal 3. Design and implement a finite impulse response (FIR) digital filter using the optimum FIR design method 4. Quantify finite word-length effects and coefficient quantization effects in FIR digital filter implementation 5. Design and implement an adaptive FIR digital filter using the Least Mean Square (LMS) algorithm 6. Explain the principles of DSP realtime implementation 7. Work as part of a team

Time Allowance for Constituent Elements		
Lectures		12 hours
Tutorials		12 hours
Project:		39 hours
Research	6 hours	
Design	6 hours	
Build/Test	6 hours	
Meetings	6 hours	
Documentation	6 hours	
Presentations	9 hours	
Total	39 hours	
Independent study & online interaction		60 hours
Exam		2 hours

	125 hours

Indicative Syllabus
➢ Introduction: Summary of GE301 Signal & Systems course, Real-time processing of signals, Motivation examples: Speech compression, Image compression ➢ Discrete Transform Techniques: FFT, Fast convolution using the FFT, Correlation, Fast correlation, DCT, Walsh transform, Hadamard transform, Spectral analysis, Short-Time Fourier Transform (Spectrogram) ➢ Finite Impulse Response Digital Filter Design and Implementation: Review of FIR design issues, The optimal FIR design method, FIR realization, Transversal structure, Linear phase structure, Analysis of finite word-length effects, Coefficient quantization effects, Roundoff and Overflow errors, FIR implementation on a DSP microprocessor ➢ Infinite Impulse Response Digital Filter Design and Implementation: Review of IIR design issues, Pole-zero placement method, Realization structures for IIR filters, Analysis of finite word-length effects, IIR implementation on a DSP microprocessor ➢ Multirate Digital Signal Processing: Sample rate conversion, Efficient techniques, Polyphase filter sample rate conversion ➢ Adaptive Digital Filters: The Wiener filter, The LMS adaptive algorithm, Adaptive speech compression ➢ Two- & Three-Dimensional DSP: DCT-based still image compression, Subband coding, Wavelet transform, 2-D filtering, Edge detection ➢ DSP Hardware: Fixed-point DSPs, Floating-point DSP, Interface hardware

Assessment Criteria	
Semester Examination Continuous Assessment: Individual logbooks (15%) Group project report (15%) Individual Project Interviews (20%)	50% 50%
Penalties: Continuous assessments components cannot be repeated, in general. **Pass Standard and any Special Requirements for Passing Modules**: In order to pass this module, students must achieve at least 30% in both the final exam and the combined continuous assessment components separately, and an overall mark of at least 40%. **Requirements for Autumn Supplemental Examination**: The continuous assessment mark is carried	

forward to the Autumn examinations as there is no facility available for repeating the continuous
assessment components of the course.

Continual Assessment Results: Continuous assessment components will be corrected within two weeks. Results and corrected scripts will be available for viewing upon request.

Assessment Philosophy

The group project provides an opportunity for the students to work as part of a team (see learning outcome 7) on a DSP project of their choice. A typical project will include learning outcomes 1 thru 4 inclusive. Each student is required to maintain an individual project logbook which will be used during the project interviews. The end-of-semester examination is designed to assess learning outcomes 1-6 and accounts for 50% of the overall marks.

Course Text	• Digital Signal Processing - A Modern Introduction, Ashok Ambardar, Michigan Technological University, International Student Edition, 2007, ISBN: 9788131501795.
Reference	• Digital Signal Processing, System Analysis and Design. Paulo S. R. Diniz, Eduardo A. B. da Silva and Sergio L. Netto. Cambridge University Press 2002. ISBN 0 521 02513 3 (paperback) • The Scientist and Engineer's Guide to Digital Signal Processing, by Steven W. Smith, California Technical Publishing, 1997. www.dspguide.com

Programmes currently utilising module

BE in Computer Engineering
BE in Electronic Engineering
BE in Communications Engineering

Appendix 4 – Quantitative Data Reliability Analysis

Test 1 – IBM SPSS Cronbach alpha for first 24 responses Q1 parts 1 to 8 inclusive

```
RELIABILITY
  /VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006 VAR00007
VAR00008
  /SCALE('Cronbach_alpha_1to8') ALL
  /MODEL=ALPHA
  /STATISTICS=DESCRIPTIVE SCALE CORR
  /SUMMARY=TOTAL.
```

Reliability

Notes

Output Created		03-AUG-2016 14:05:45
Comments		
Input	Data	F:\Aalborg MPBL\Sem 4\Student attitude to PBL\Responses\EEng24Q1.sav
	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	24
	Matrix Input	
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the procedure.

Syntax		RELIABILITY /VARIABLES=VAR00001 VAR00002 VAR00003 VAR00004 VAR00005 VAR00006 VAR00007 VAR00008 /SCALE('Cronbach_alpha_1to8') ALL /MODEL=ALPHA /STATISTICS=DESCRIPTIVE SCALE CORR /SUMMARY=TOTAL.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.03

Scale: Cronbach_alpha_1to8

Case Processing Summary

		N	%
Cases	Valid	24	100.0
	Excluded[a]	0	.0
	Total	24	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.370	.480	8

Item Statistics

	Mean	Std. Deviation	N
VAR00001	4.2500	.84699	24
VAR00002	4.5417	.65801	24
VAR00003	2.2083	1.47381	24
VAR00004	4.2917	.75060	24
VAR00005	4.2500	.73721	24
VAR00006	4.3333	.70196	24

VAR00007	4.4583	.65801	24
VAR00008	4.7500	.53161	24

Inter-Item Correlation Matrix

	VAR01	VAR02	VAR03	VAR04	VAR05	VAR06	VAR07	VAR08
VAR01	1.000	.215	-.287	-.256	-.383	-.073	-.215	.048
VAR02	.215	1.000	-.121	-.158	-.022	.063	-.297	-.093
VAR03	-.287	-.121	1.000	.100	.230	.014	.032	.069
VAR04	-.256	-.158	.100	1.000	.727	.550	.510	-.136
VAR05	-.383	-.022	.230	.727	1.000	.840	.560	.055
VAR06	-.073	.063	.014	.550	.840	1.000	.596	.117
VAR07	-.215	-.297	.032	.510	.560	.596	1.000	.218
VAR08	.048	-.093	.069	-.136	.055	.117	.218	1.000

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
VAR01	28.8333	9.188	-.305	.416	.542
VAR02	28.5417	8.346	-.115	.222	.439
VAR03	30.8750	6.201	-.004	.200	.515
VAR04	28.7917	6.259	.404	.639	.221
VAR05	28.8333	5.536	.652	.888	.093
VAR06	28.7500	5.761	.619	.834	.125
VAR07	28.6250	6.592	.389	.531	.246
VAR08	28.3333	7.797	.088	.166	.365

Scale Statistics

Mean	Variance	Std. Deviation	N of Items
33.0833	8.341	2.88801	8

Test 2 – IBM SPSS Split-half test for first 24 responses Q1 parts 1 to 8 inclusive

Reliability Statistics

Cronbach's Alpha	Part 1	Value	-.446[a]
		N of Items	4[b]
	Part 2	Value	.749
		N of Items	4[c]
	Total N of Items		8
Correlation Between Forms			.210
Spearman-Brown Coefficient	Equal Length		.347
	Unequal Length		.347
Guttman Split-Half Coefficient			.343

a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

b. The items are: VAR00001, VAR00002, VAR00003, VAR00004.

c. The items are: VAR00005, VAR00006, VAR00007, VAR00008.

Test 3 – IBM SPSS Cronbach alpha for first 24 responses Q1 parts 4 to 8 inclusive

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.794	.772	5

Test 4 – IBM SPSS Split-half test for first 24 responses Q1 parts 4 to 8 inclusive

Reliability Statistics

Cronbach's Alpha	Part 1	Value	.877
		N of Items	3[a]
	Part 2	Value	.351
		N of Items	2[b]
	Total N of Items		5
Correlation Between Forms			.443
Spearman-Brown Coefficient	Equal Length		.614
	Unequal Length		.621
Guttman Split-Half Coefficient			.511

a. The items are: VAR00004, VAR00005, VAR00006.

b. The items are: VAR00007, VAR00008.

Test 5 – IBM SPSS Cronbach alpha for first 24 responses Q1 parts 1 to 3 inclusive

Reliability Statistics

Cronbach's Alpha[a]	Cronbach's Alpha Based on Standardized Items[a]	N of Items
-.410	-.223	3

a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

Test 6 – IBM SPSS Split-half test for first 24 responses Q1 parts 1 to 3 inclusive

Cronbach's Alpha	Part 1	Value	.344
		N of Items	2[a]
	Part 2	Value	.[b]
		N of Items	1[c]
	Total N of Items		3
Correlation Between Forms			-.274
Spearman-Brown Coefficient	Equal Length		-.756[d]
	Unequal Length		-.449[d]
Guttman Split-Half Coefficient			-.731

a. The items are: VAR00001, VAR00002.

b. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

Test 7 – R Cronbach alpha for first 24 responses Q1 parts 1 to 8 inclusive

```
> alpha(x,check.keys=TRUE)

Reliability analysis
Call: alpha(x = x, check.keys = TRUE)

  raw_alpha std.alpha G6(smc) average_r S/N ase mean   sd
      0.66      0.71     0.8      0.23 2.4 0.1  3.4 0.46

 lower alpha upper     95% confidence boundaries
0.45 0.66 0.86
```

```
 Reliability if an item is dropped:
          raw_alpha std.alpha G6(smc) average_r S/N alpha se
VAR00001-      0.62      0.69    0.79      0.24 2.3    0.119
VAR00002-      0.66      0.72    0.81      0.27 2.6    0.107
VAR00003       0.73      0.72    0.82      0.27 2.6    0.081
VAR00004       0.59      0.64    0.74      0.21 1.8    0.125
VAR00005       0.54      0.60    0.66      0.17 1.5    0.140
VAR00006       0.60      0.65    0.71      0.21 1.8    0.120
VAR00007       0.59      0.63    0.75      0.19 1.7    0.123
VAR00008       0.68      0.74    0.83      0.29 2.9    0.104

 Item statistics
           n raw.r std.r r.cor r.drop mean   sd
VAR00001- 24  0.56  0.52  0.44   0.37  1.8 0.85
VAR00002- 24  0.37  0.40  0.26   0.20  1.5 0.66
VAR00003  24  0.58  0.40  0.26   0.21  2.2 1.47
VAR00004  24  0.66  0.69  0.68   0.52  4.3 0.75
VAR00005  24  0.81  0.83  0.90   0.72  4.2 0.74
VAR00006  24  0.61  0.68  0.72   0.47  4.3 0.70
VAR00007  24  0.66  0.75  0.72   0.54  4.5 0.66
VAR00008  24  0.22  0.30  0.13   0.08  4.8 0.53

Non missing response frequency for each item
           1    2    3    4    5 miss
VAR00001 0.00 0.04 0.12 0.38 0.46    0
VAR00002 0.00 0.00 0.08 0.29 0.62    0
VAR00003 0.46 0.21 0.17 0.00 0.17    0
VAR00004 0.00 0.04 0.04 0.50 0.42    0
VAR00005 0.00 0.00 0.17 0.42 0.42    0
VAR00006 0.00 0.00 0.12 0.42 0.46    0
VAR00007 0.00 0.00 0.08 0.38 0.54    0
VAR00008 0.00 0.00 0.04 0.17 0.79    0
Warning message:
In alpha(x, check.keys = TRUE) :
  Some items were negatively correlated with total scale and were
automatically reversed.
 This is indicated by a negative sign for the variable name.
```

Test 8 – R ω test for first 24 responses Q1 parts 1 to 8 inclusive

```
> omega(x)
Loading required namespace: GPArotation
Omega
Call: omega(m = x)
Alpha:                 0.71
G.6:                   0.8
Omega Hierarchical:    0.51
Omega H asymptotic:    0.62
Omega Total            0.82

Schmid Leiman Factor loadings greater than  0.2
             g   F1*   F2*   F3*   h2   u2   p2
VAR00001-  0.27        0.57        0.41 0.59 0.18
VAR00002-  0.23 -0.28        0.39 0.31 0.69 0.17
VAR00003               0.40        0.17 0.83 0.07
VAR00004   0.55  0.37  0.34        0.57 0.43 0.53
VAR00005   0.67  0.67  0.32        1.00 0.00 0.45
VAR00006   0.63  0.73 -0.21        0.98 0.02 0.40
VAR00007   0.69              0.53 0.78 0.22 0.60
```

```
VAR00008                          0.06 0.94 0.32

With eigenvalues of:
   g  F1*  F2*  F3*
1.76 1.23 0.79 0.49

general/max  1.43   max/min =   2.52
mean percent general =  0.34    with sd =  0.19 and cv of  0.55
Explained Common Variance of the general factor =  0.41

The degrees of freedom are 7  and the fit is  0.23
The number of observations was  24  with Chi Square =  4.08  with prob <
0.77
The root mean square of the residuals is  0.05
The df corrected root mean square of the residuals is  0.11
RMSEA index =  0  and the 90 % confidence intervals are  NA 0.171
BIC =  -18.16

Compare this with the adequacy of just a general factor and no group
factors
The degrees of freedom for just the general factor are 20  and the fit is
1.96
The number of observations was  24  with Chi Square =  36.96  with prob <
0.012
The root mean square of the residuals is  0.16
The df corrected root mean square of the residuals is  0.19

RMSEA index =  0.234  and the 90 % confidence intervals are  0.087 0.282
BIC =  -26.6

Measures of factor score adequacy
                                                 g  F1*  F2*   F3*
Correlation of scores with factors            0.77 0.83 0.94  0.66
Multiple R square of scores with factors      0.60 0.69 0.89  0.44
Minimum correlation of factor score estimates 0.20 0.38 0.78 -0.13

 Total, General and Subset omega for each subset
                                                 g  F1*  F2*  F3*
Omega total for total scores and subscales    0.82 0.90 0.42 0.55
Omega general for total scores and subscales  0.51 0.47 0.06 0.26
Omega group for total scores and subscales    0.25 0.44 0.36 0.28
>
```

Test 9 – R ω test for first 24 responses Q1 parts 4 to 8 inclusive

```
> alpha(x,check.keys=TRUE)

Reliability analysis
Call: alpha(x = x, check.keys = TRUE)

  raw_alpha std.alpha G6(smc) average_r S/N   ase mean  sd
      0.79      0.77    0.83       0.4 3.4 0.061  4.4 0.5
>
> omega(x)
Omega
Call: omega(m = x)
Alpha:                 0.77
G.6:                   0.83
Omega Hierarchical:    0.78
Omega H asymptotic:    0.85
Omega Total            0.91
```

Test 10 – R α and ω test for first 24 responses Q1 parts 1 to 3 inclusive

```
> alpha(x,check.keys=TRUE)

Reliability analysis
Call: alpha(x = x, check.keys = TRUE)

  raw_alpha std.alpha G6(smc) average_r  S/N  ase mean   sd
       0.4      0.44    0.35      0.21 0.79 0.18  4.2 0.71

 lower alpha upper     95% confidence boundaries
0.04 0.4 0.76

> omega(x)
Omega
Call: omega(m = x)
Alpha:                 0.44
G.6:                   0.35
Omega Hierarchical:    0.47
Omega H asymptotic:    0.92
Omega Total            0.51
```

Test 11 – IBM SPSS Cronbach alpha for All responses Q1 parts 1 to 8 inclusive

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.414	.548	8

Test 12 – IBM SPSS Split-half test for All responses Q1 parts 1 to 8 inclusive

Reliability Statistics

Cronbach's Alpha	Part 1	Value	-.149[a]
		N of Items	4[b]
	Part 2	Value	.675
		N of Items	4[c]
	Total N of Items		8
Correlation Between Forms			.286
Spearman-Brown Coefficient	Equal Length		.445
	Unequal Length		.445
Guttman Split-Half Coefficient			.444

a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

b. The items are: VAR00001, VAR00002, VAR00003, VAR00004.

c. The items are: VAR00005, VAR00006, VAR00007, VAR00008.

Test 13 – IBM SPSS Cronbach alpha for All responses Q1 parts 4 to 8 inclusive

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.744	.722	5

Test 14 – IBM SPSS Split-half test for All responses Q1 parts 4 to 8 inclusive

Reliability Statistics

Cronbach's Alpha	Part 1	Value	.811
		N of Items	3[a]
	Part 2	Value	.383
		N of Items	2[b]
	Total N of Items		5
Correlation Between Forms			.385
Spearman-Brown Coefficient	Equal Length		.556
	Unequal Length		.563

Guttman Split-Half Coefficient	.475

a. The items are: VAR00004, VAR00005, VAR00006.

b. The items are: VAR00007, VAR00008.

Test 15 – IBM SPSS Cronbach alpha for All responses Q1 parts 1 to 3 inclusive

Reliability Statistics

Cronbach's Alpha[a]	Cronbach's Alpha Based on Standardized Items	N of Items
-.113	.068	3

a. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

Test 16 – IBM SPSS Split-half test for All responses Q1 parts 1 to 3 inclusive

Reliability Statistics

Cronbach's Alpha	Part 1	Value	.673
		N of Items	2[a]
	Part 2	Value	.[b]
		N of Items	1[c]
	Total N of Items		3
Correlation Between Forms			-.251
Spearman-Brown Coefficient	Equal Length		-.668[d]
	Unequal Length		-.419[d]
Guttman Split-Half Coefficient			-.660

a. The items are: VAR00001, VAR00002.

b. The value is negative due to a negative average covariance among items. This violates reliability model assumptions. You may want to check item codings.

c. The item is: VAR00003

d. The correlation between forms (halves) of the test is negative. This violates reliability model assumptions. Statistics which are functions of this value may have estimates outside theoretically possible ranges.

Test 17 – R Cronbach alpha and omega for All responses Q1 parts 1 to 8 inclusive

```
> alpha(x,check.keys=TRUE)

Reliability analysis
Call: alpha(x = x, check.keys = TRUE)

  raw_alpha std.alpha G6(smc) average_r S/N  ase mean  sd
      0.41      0.55    0.67      0.13 1.2 0.12  3.8 0.4

 lower alpha upper     95% confidence boundaries
0.16 0.41 0.65

> omega(x)
Omega
Call: omega(m = x)
Alpha:                 0.62
G.6:                   0.71
Omega Hierarchical:    0.2
Omega H asymptotic:    0.25
Omega Total            0.8

Warning message:
In alpha(x, check.keys = TRUE) :
  Some items were negatively correlated with total scale and were
automatically reversed.
 This is indicated by a negative sign for the variable name.
```

Test 18 – R ω test for All responses Q1 parts 1 to 8 inclusive

```
> omega(x)
Loading required namespace: GPArotation
Omega
Call: omega(m = x)
Alpha:                 0.62
G.6:                   0.71
Omega Hierarchical:    0.2
Omega H asymptotic:    0.25
Omega Total            0.8
```

Test 19 – R α and ω test for All responses Q1 parts 4 to 8 inclusive

```
> alpha(x,check.keys=TRUE)

Reliability analysis
Call: alpha(x = x, check.keys = TRUE)

  raw_alpha std.alpha G6(smc) average_r S/N   ase mean   sd
      0.74      0.72    0.73      0.34 2.6 0.051  4.4 0.47

 lower alpha upper     95% confidence boundaries
0.64 0.74 0.84
```

```
Omega
Call: omega(m = x)
Alpha:                 0.72
G.6:                   0.73
Omega Hierarchical:    0.65
Omega H asymptotic:    0.76
Omega Total            0.85
```

Test 20 – R ω test for All responses Q1 parts 1 to 3 inclusive

```
> alpha(x,check.keys=TRUE)

Reliability analysis
Call: alpha(x = x, check.keys = TRUE)

  raw_alpha std.alpha G6(smc) average_r S/N  ase mean   sd
      0.53      0.59    0.53      0.33 1.5 0.11  3.8 0.85

 lower alpha upper     95% confidence boundaries
0.31 0.53 0.75

> omega(x)
Omega
Call: omega(m = x)
Alpha:                 0.59
G.6:                   0.53
Omega Hierarchical:    0.66
Omega H asymptotic:    0.83
Omega Total            0.79
```

Summary of Reliability Statistical Analysis

Test Number	Input Data	Software Platform	α	α_s	Split-Half		ω_t
1	First 24 responses: all 8 items	SPSS	.370	.480			
2					-.446	.749	
7, 8		R	0.66	0.71			0.82
3	First 24 responses: items 4 to 8	SPSS	.794	.772			
4					.877	.351	
9		R	.79	.77			.91
5	First 24 responses: items 1 to 3	SPSS	-.410	-.223			
6					.344	-ve	
10		R	0.4	0.44			.51
11	All responses, all 8 items	SPSS	.414	.548			
12					-.149	.675	
17		R	0.41	0.55			0.8
13	All responses: items 4 to 8	SPSS	.744	.722			
14					.811	.383	
19		R	0.74	0.72			0.79
15	All responses: items 1 to 3	SPSS	-.113	.068			
16					.673	-ve	
20		R	0.53	0.59			0.79

Appendix 5 – Email to Accreditation Board for Engineering and Technology (ABET)

Fri 08/07/2016 12:35

Bob Lawlor

Revised ABET criteria

To 'accreditation@abet.org'

Dear ABET Board of Delegates,

Sorry this email is after the June 15th deadline. I hope it's not too late to be considered by the board.

It's a minor concern relating to the alignment of the curriculum criteria with Student outcome 7 which states:

An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty.

This is a good outcome which aligns well with much research relating to the merits of collaborative and cooperative learning. See for example Freeman (2014).

My concern is that in the proposed revised curriculum criteria there's no mention of teams. I fear that if this very important student outcome is not explicitly aligned with the curriculum criteria then many engineering program boards may neglect to effectively integrate team based collaborative and cooperative learning elements into their programs resulting in what Prince (2004) notes as 'employers frequently identify team skills as a critical gap in the preparation of engineering students' (pg 5).

Best Regards

Bob Lawlor
Frustrated facilitator of learning and important skills development
Dept of Electronic Engineering
Maynooth University
Ireland.

Freeman, S., Eddya, S. L., McDonough, M., Smith, M. K., Okoroafora, N., Jordta, H., and Wenderoth P, P., (2014). "Active learning increases student performance in science, engineering, and mathematics". Proceedings of the National Academy of Sciences of the United States of America, vol. 111 no. 23 pp. 8410-8415. Available online at: http://www.pnas.org/content/111/23/8410 (accessed 30 June 2016).

Prince, M., (2004). Does Active Learning Work? A Review of the Research. J. Engr. Education, 93(3), 223-231 (2004).