2010-01-01

A Project-Based Learning Approach to Applied Craft Calculations Within Apprenticeship Education: An Action Research Study

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M.A. (Third Level Learning & Teaching) **2010**

Declaration

I hereby certify that the material, which is submitted in this thesis towards the award of **Masters (M.A.) in Third Level Learning and Teaching,** is entirely my own work and has not been submitted for any academic assessment other than part-fulfilment of the above named award.

Future students may use the material contained in this thesis provided that the source is acknowledged in full.

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Abstract

Using an Action Research methodology, this study was based in Dublin Institute of Technology and conducted with the cooperation of three groups of Phase Six Plumbing apprentices over a ten-month period (three cycles). The main aim of the research project was to establish if a deeper understanding and application of Building Services Applied Calculations could be achieved through the implementation of Project-Based Learning within Apprenticeship Education? Research literature shows that not only in Ireland but also abroad, third level education is experiencing what is described as a 'maths problem'. With applied calculations and mathematics being a fundamental and essential part of Building Services Engineering in general, and also the FÁS phase six plumbing curriculum, many students are failing module examinations because of an inadequate understanding of basic mathematical principles. The question was examined through the design, implementation and evaluation of real world plumbing mathematical tasks and problems applied within a project dwelling. The mathematical calculations also followed closely, the level of mathematical competency required within the FÁS phase six plumbing curriculum for compulsory end of term summative assessments. The research was underpinned by a genuine commitment to enhance the learning experience of my students and also for personal professional improvement and self-development.

The qualitative data gathered and analysed from questionnaires, focus groups, observational diaries and reflective diaries culminated in findings to show that this learning paradigm significantly improved the mathematical competence, understanding, motivation and confidence of those participating in the research. Noticeable improvements in other key skills such as group participation, reflective learning, and self-assessment also emerged through this pedagogical implementation.

The main recommendations arising from the study are that a form of student-centred learning such as project-based learning aligned to continuous and formative assessments could be used to better reflect projects and problems typical of those found in real life craft working situations. This allows students to work on and understand meaningful issues and topics where they find real solutions to real problems.

Acknowledgements

I would like to thank the following people whose help and support was invaluable throughout this research study.

My supervisor Mr Lloyd Scott, for his continuous support, enthusiasm, advice and encouragement throughout this research project. His guidance throughout the entire research process was inspirational to the completion of this thesis.

The staff in the D.I.T Learning, Teaching and Technology Centre, for all their help and encouragement over the past three years. A special word of appreciation to Dr. Marian Fitzmaurice for all her work in coordinating the final MA year and for her continual help and motivation whenever it was sought.

To the library staff in D.I.T Bolton Street and in particular Roísín Guilfoyle, Diana Mitchell and Bill Murphy for their patience, understanding and help throughout the year.

To all of the students who selflessly took part in the research for all of the right reasons. I am extremely grateful to each of them. Without them this action research project would not have been possible.

I would also like to thank Dr. Louis Gunnigan, Head of School of Construction and Mr John Smartt, Assistant Head of School, Construction Skills, for their encouragement in the setting up of this research project.

A special word of thanks to Beirní Ní Chuinn, who painstakingly read over each chapter of this thesis and advised so expertly on grammatical issues.

To my family and friends especially Aisling, who put up with me, encouraged me, and listened to me over the past year.

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List of Abbreviations

AARE	Australian Association for Research in Education
ACC	An Cheard Chomhairle: The Apprenticeship Board
AERA	American Educational Research Association
AnCo	An Comhairle Oiliuna
BERA	British Educational Research Association
CAO	Central Applications Office
CIPHE	Chartered Institute of Plumbing and Heating Engineering
CPD	Continued Professional Development
CPS	Competent Person Scheme
D.I.T	Dublin Institute of Technology
DoE&S	Department of Education and Skills
EEC	European Economic Community
ESF	European Social Fund
ESRC	Economic and Social Research Council
EU	European Union
FÁS	Foras Aiseanna Saothair (Training & Employment Authority)
FDTL	Fund for the Development of Teaching and Learning
FETAC	Further Education and Training Awards Council
HEA	Higher Education Authority
IS	Irish Standard
M.A.	Master of Arts
MTC	Minimum Technical Competency
NAAC	National Apprenticeship Advisory Committee
NCCA	National Council for Curriculum and Assessment
NCTM	National Council of Teachers of Mathematics
NFQ	National Framework of Qualifications
NSAI	National Standards Authority of Ireland
NVQ	National Vocational Qualification (United Kingdom)
OECD	Organisation for Economic Co-operation and Development
P.E.S.P	Programme for Economic and Social Progress
PBL	Project-Based Learning
PBLE	Project Based Learning in Engineering

PISA	Programme for International Student Assessment
RTC	Regional Technical Colleges
TAFE	Technical and Further Education (Consortium in Australia)
TIMSS	Third International Mathematics and Science Study
USA	United States of America

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Chapter One

Context of the Research

1.1 Introduction

Writing a thesis or dissertation did not strike me as easy, particularly from the present position as a writer at the beginning of the first page. However, all major journeys start with a single step, so firstly I thought it appropriate to give an outline of myself and to place in context my current range of teaching duties and responsibilities.

My current teaching practice in Building Services Engineering within Dublin Institute of Technology (D.I.T.) ranges from full time level 8 Honours Degree, part time level 7 Ordinary Degree to level 6 National Craft Certificate Apprenticeship programmes (NFQ, 2009a). Occasionally I have also had private companies attending college for one, or two-day, staff training and Continued Professional Development (CPD) courses. Within this teaching remit there is a broad cross section of students coming from a wide range of socio-economic and educational backgrounds (G. Gibbs, 2006b). The number and range of abilities of these students entering third level institutions has grown dramatically over the years along with learners who previously were not eligible for many courses, now having access (Hourigan & O'Donoghue, 2007). The start of the Irish 2009/10 academic year saw the largest jump ever in numbers accepting places through the Central Applications Office (CAO) in higher education institutions ("Higher Education Authority," 2009). This study will focus specifically on level 6 National Craft Certificate Apprenticeship, and in particular on the subject of applied calculations and mathematics within the craft of plumbing, at phase six.

With applied calculations and mathematics being a fundamental and essential part of Building Services Engineering in general, and also the FÁS phase six plumbing curriculum (Appendix 1), many of these students are failing module examinations because of an inadequate understanding of basic mathematical principles. Many of the students entering third level education demonstrate mathematical knowledge that is fragmented, variable and insecure (Hourigan & O'Donoghue, 2007). There is also an insufficient understanding of the mathematical relationship to real world practical problems, thus supporting the view that students need much stronger experiences in building real world and mathematical world connections (Klymchuk, Zverkova, Gruenwald, & Sauerbier, 2008). In other words, many students don’t know why they are doing a particular mathematical problem and seem unable to place it into a typical real life, mechanical services situation. The traditional format of mathematics instruction seems not to have succeeded in providing the skills students need to work cooperatively to solve problems in industry (Johnson & Fischbach, 1992).

With the concerns outlined above, it was the intention of this action research study to investigate if *a deeper understanding and application of Building Services Applied Calculations and Mathematics can be achieved through the implementation of Project-Based Learning within Apprenticeship Education*? The action research was conducted with three consecutive groups of phase six plumbing apprentices over a ten-month period (three cycles). Each of these groups comprised of sixteen students making a total of forty-nine people, which included myself participating in the action research study. As with all research particular attention must be paid to local, national and international ethical standards. How this study complies with these recommendations is fully outlined in Section 1.5.

Previous research on apprentices and apprenticeship in Ireland has been limited to date, particularly in relation to apprenticeship education (Goggin, 2004). The small amount of research that is available mainly deals with the Irish apprenticeship system and its history as a whole, (Conway, 2007; ESF, 1999; Field & O'Dubhchair, 2001; Hinch, 2007; Nyhan, 2009; O'Connor, 2004, 2006; O'Connor & Harvey, 2001; Ryan, 2004). There is also a related study where Hinch, (2007) deals specifically with blended face-to-face and e-learning of mathematics within phase four of apprenticeship education. Despite an exhaustive search there appears to be no literature on the implementation of a project-based learning paradigm within the Irish apprenticeship education system. While this study is based only on a single subject (applied calculations and mathematics) it may fill this gap and provide the foundation for further research whereby more subjects could be implemented within the same student project. The literature review in Chapter Two also looks further afield to the mathematical problems experienced by students internationally.

1.2 Context of the Research

I have been directly involved in the off-the-job training and education of apprentice plumbers as a lecturer since 2004. Previous to this I was actively involved in the on-the-job training and education of apprentice plumbers since 1993 as part of my duties as a contracts manager. Throughout this time I have become increasingly aware of the problems that many of these students have both with the understanding and implementation of trade calculations and mathematics. I have experienced this from both sides, firstly where I have witnessed apprentices being unable to carry out calculations on site, or the inability to understand which calculations to use or adapt to use.

Secondly from the classroom situation where many apprentices rely on rote memory of formulas for end of term examination purposes and cannot perceive how these calculations can be implemented into everyday craft situations. These calculations and mathematics are often not meaningful to apprentices who are attempting to apply consistent theoretical formulas to situations in the workplace which may require varying definitions and solutions to problems (Tanggaard, 2007). This is causing problems not only for the apprentices but also for their employers who expect a certain level of competency from their employees returning to site after eleven weeks of off-the-job training and education. The government in the United Kingdom has also expressed concern that many apprentices lack basic skills and have responded with the inclusion of Key Skills requirements (concerning the use of numeracy and literacy in particular) (McIntosh, 2005) in all of their advanced apprenticeship programmes (Ryan, Gospel, & Lewis, 2006).

In the past number of years there are 336 plumbing apprentices passing through the Department of Construction Skills within D.I.T. on an annual basis (HEA-Forfás, 2007). This represents only 11.8% of all apprentices who on average attend D.I.T. annually (HEA-Forfás, 2007). Of the 336 plumbing apprentices 192 are phase six students with the remainder studying the phase four curriculum.

With such a large number of student apprentices attending college annually, teachers have a professional duty to them, their employers and to FÁS, to provide a professional service that adequately equips them with the skills and theoretical underpinnings of their occupation that is needed to apply their craft to real practice.

With the high amount of student apprentices progressing to National Craft Certificate level annually, apprenticeship can also provide a route for advancing to further full or part-time education. It was also agreed between the Department of Education and Science and the Department of Enterprise Trade and Employment that the National Craft Certificate should provide a basis for progression (ESF, 1999). In the introduction to the most recent revision of the their plumbing curriculum (Revision 2.2), FÁS also state that apprenticeship enables a person to seek progression through further education and training within the national Framework of Qualifications (FÁS, 2006b). Many students seem interested in this route and often make enquiries of further educational progression options linked to their craft. Many apprentices are, however, content to finish their training and education with the National Craft Certificate and do not want to feel as if they are going back into the classroom, as being attached to a real employer and learning on-the-job is a major attraction of apprenticeship (McIntosh, 2005). However, within a study in England, young people expressed concerns that taking up an apprenticeship would not provide a route for their progression into higher education (Beck, Fuller, & Unwin, 2006) and was seen as an educational terminus rather than a way-station (Ryan, et al., 2006).

There is also significant debate as to where exactly apprenticeship lies within the educational, vocational and training fields (Ryan, 2000). Within the Irish National Framework of Qualifications, qualified crafts persons are placed at level six and are awarded a Further Education and Training Awards Council (FETAC) advanced certificate known as the National Craft Certificate. The majority of level six holders take up positions of employment, although a certificate holder at this level may also transfer to a programme leading to the next level of the framework (NFQ, 2009a) (Appendix 2). The Irish National Framework of Qualifications links all Irish education and training to each other and is a system of ten levels. It is designed to incorporate awards made for all kinds of learning wherever it is gained and while putting the needs of the learner first it supports the national agenda of moving towards a ‘lifelong learning society’. It also seeks to eliminate education and training cul-de-sacs or terminus as mentioned above (NFQ, 2009b). A more in-depth analysis of educational and vocational apprenticeship training is carried out in Section 2.2.2 of Chapter Two.

For those plumbing apprentices wishing to progress within their craft, there may also be an question of post-qualification options. Other than a move to a full or part-time degree course in building services engineering, the only plumbing related option presently available in Ireland is the part-time advanced plumbing (DT151) course offered by Dublin Institute of Technology (D.I.T, 2009). At present this 100% project-based course is only catering for approximately thirty students every two years, which has subsequently developed a waiting list for entry. With the current high rate of unemployment, many more phase six apprentices are now making enquiries regarding post-apprenticeship courses.

This action research was conducted with both apprenticeship progression options in mind. Firstly with a move to mathematical project-based learning it was hoped to better equip apprentices with a deeper understanding and knowledge of how and where plumbing calculations can used in their line of work. Secondly it was hoped that this learning and teaching paradigm would also give apprentices added confidence in the use of applied mathematics for progression into further education.

The majority of building contracts and the associated services are normally grouped together to form a complete project. This action research study followed a similar pattern where real world plans and elevations were used with apprentices, to apply plumbing design techniques and calculations to form a complete building services project. It was hoped that a more thorough understanding of these calculations could be gained through the realisation of exactly where these design principles can be incorporated in reality. Students participating in project-based learning may also benefit from their own errors, where reflection is encouraged and also required for a final workable outcome to be produced (Barron, et al., 1998). As there is usually more than one way to solve the various tasks and problems, students also get to know the different uses and adaptability of calculations, which may be favoured for a particular application.

This change of learning and teaching paradigm was intended to provide for a deeper understanding of the use, transposition and application of formulas and calculations with a move from just memorising for examination purposes. The use of project-based learning and the particular type used for this research is further discussed in Chapter Two.

Along with apprenticeship training there also appears to be a changing nature of general education not only in Ireland but also internationally. As recent as November 2009 discussions are in place in Ireland to review the National Junior Certificate examination which has been in existence since it replaced the Intermediate Certificate in 1992 (McMorrow, 2009). Over time the Junior Certificate has become a mirror image of the Leaving Certificate, giving little opportunity for independent learning (Irishtimes.com, 2009). These discussions, on a new examination style with a greater focus on independent learning, may replace the current Junior Certificate which is seen as "driven by rote learning and examination pressures, rather than the promotion of real understanding and skills", as acknowledged by the Minister for Education, Batt O'Keeffe (Irishtimes.com, 2009).

This teaching by 'rote learning' rather than 'learning by understanding' with links to the needs of the everyday world, are just some of the current drawbacks with mathematical education identified by the National Council for Curriculum and Assessment (NCCA), and also elaborated upon in an exhaustive report compiled by Engineers Ireland as recently as February 2010 (Engineers-Ireland, 2010). The Department of Education and Skills also want a greater emphasis on assessment for learning, practical, project and portfolio assessment and self-directed learning (NCCA & DoE&S, 2002). The forthcoming discussion paper from the National Council for Curriculum and Assessment (NCCA) is expected to back more continuous assessment and project work in the promotion of understanding (Flynn, 2009), through active teaching methods (Engineers-Ireland, 2010).

A whole new approach to mathematics education 'Project Maths' is also currently being introduced in Ireland at junior and senior cycle levels. Project Maths places an emphasis on understanding and interpretation of problems rather than rote learning (Engineers-Ireland, 2010). "One of the main objectives of Project Maths is that mathematics can be learned in contexts which establishes links between mathematics and other subjects as well as real world applications" (Engineers-Ireland, 2010, p. 39). With problem solving and teamwork being promoted in this approach, it also very well describes project-based learning.

It is not only Ireland that has recognised the need for educational improvement; in the Netherlands there is also recent moves to reform their educational programmes to make them more competence based (Onstenk & Blokhuis, 2007). Instead of concentrating on knowledge acquisition, they are attempting to help prevocational secondary school learners acquire a combination of knowledge, skills, and attitudes that they will need in their chosen vocation (i.e. competences) (Seezink, Poell, & Kirschner, 2009). In Hong Kong, project-based learning has also been introduced as one of the key educational innovations in their education reform (Education-Commission, 2000). The review of their education system is to include the curricula, the academic structure and the assessment mechanisms at various stages, as well as the interface between different stages of education (Education-Commission, 2000). With so much emphasis on the need to review and reform educational systems to a more learner-centred environment, it was thought necessary to also study the Irish apprenticeship educational system with particular reference to the trade of plumbing. This was in an effort to review why a move to project-based learning may provide students with a deeper understanding of applied mathematics than that offered through traditional lecture-centric methods.

1.2.1 Irish Apprenticeship Educational System

Apprenticeships are an important component of national economies as they play a key role in skill formation and form pathways into labour markets (Harris & Simons, 2005). There is also "the contribution to economic performance of the intermediate skills that apprenticeship produces" (Ryan, 2000, p. 42). Apprenticeship education in Ireland has changed from the time-served system inherited from the UK to a standards-based system that includes mandatory periods of off-the-job phases of theoretical and practical education along with work-based phases spanning over a four-year period (O'Connor & Mullins, 2005). The current Irish apprenticeship system can be seen as a microcosm of the wider economic and social development and transformation which took place in Ireland and gave rise to the vibrant Irish economy during the 1990s and early years of the millennium, known as the ‘Celtic Tiger’ (Nyhan, 2009).

However, “the apprenticeship tradition inherited by Ireland on gaining independence from Britain in 1922 was voluntary, non-regulated and dependent on the backing of employers” (Nyhan, 2009, p. 458). Outside of Dublin and Belfast the number of apprentices were moderately small, but the relative security and high status of these crafts made them very valuable positions (Field & O'Dubhchair, 2001). A two year full-time course of continuing education of a practical nature followed by attendance on a part-time basis during the third and fourth years of apprenticeship were just some of the recommendations made in 1927 within a report by the Commission on Technical Education, known as the Ingram Commission (O'Connor & Harvey, 2001). As a result of the many recommendations made within this report, the government introduced two new Acts, the Vocational Education Act, 1930 and the Apprenticeship Act, 1931 (O'Connor & Harvey, 2001).

These Acts were introduced at a time of severe economic depression where jobs were scarce and employer/trade-union co-operation was still in its infancy, Murphy (as cited in O'Connor & Harvey, 2001). Consequently, these Acts made very little impact on apprenticeship education and training. However, Vocational Education Committees, on their own initiatives, began organising courses for apprentices on a day and evening class basis from the 1930s through to the 1960s (O'Connor & Harvey, 2001). “A new Apprenticeship Act was passed in 1959, creating a national tripartite regulating body known as An Cheard Chomhairle (ACC, The apprenticeship board)” (Field & O'Dubhchair, 2001, p. 249). However, because of lack of support for apprentices from employers during the 1960s the Irish government moved to pass the Industrial Training Act 1967, which repealed the Apprenticeship Act of 1959 (Nyhan, 2009).

The 1967 Industrial Training Act placed apprentices under a new regulatory body with wider and statutory interests in vocational training, An Comhairle Oiliuna (AnCo) (Field & O'Dubhchair, 2001; O'Connor & Harvey, 2001). In its first report AnCo stated that the majority of apprentices were not getting enough training either on or off-the-job (O'Connor & Harvey, 2001), and although the 1967 Act gave them power to compel employers to release apprentices for off-the-job education, up to forty percent of apprentices from across the trade areas were not released (Nyhan, 2009). At this time it was still not mandatory for apprentices to pass any examination to reach craftsperson level as apprenticeship was time-served rather than standards-reached. However, AnCo training centres expanded, notably with funding from the European Social Fund, after Ireland joined the European Economic Community (EEC) in 1973. Also around this period the Department of Education introduced the national Junior and Senior trades examinations, which were usually completed in the Regional Technical Colleges (RTC) following a course of either day or block release from the workplace (O'Connor & Harvey, 2001). In 1999 the RTC's were re-designated as Institutes of Technology, of which there are now thirteen in Ireland today (O'Connor & Harvey, 2001).

Despite the history of legislated change (Field & O'Dubhchair, 2001) the Irish apprenticeship was in the 1980's an archaic, publicly unregulated and declining institution. Apprentices were certified according to time served rather than vocational achievements (Ryan, 2000). The Irish apprenticeship system had mostly followed the United Kingdom's approach until the 1980's (Ryan, 2000). Although there were many initiatives at different times since independence by Irish policy makers to break with this tradition and form a more regulated system, they were met with lack of agreement from the economic, social and educational players in their pursuits (Nyhan, 2009). In the 1986 White Paper on Manpower the apprenticeship system was criticised as being costly, inflexible and inefficient (Field & O'Dubhchair, 2001). "The Irish journey towards the establishment of a nationwide apprenticeship programme was a long and painful learning one, mirroring its attempts to introduce an industrial culture suited to its needs" (Nyhan, 2009, p. 459).

During the 1990s, however, Ireland moved towards a more continental regulatory method, and in 1993 the Apprenticeship Act established the standards-based training for 14 (now 26) (FÁS, 2009b) craft and technician occupations in industry (ESF, 1999; Nyhan, 2009; Ryan, 2000). As part of this strategy the government established a new regulatory body, an Foras Aiseanna (FÁS) which replaced AnCo under the Industrial Training Act, 1987 (O'Connor & Harvey, 2001), with responsibility for introducing the new standards based apprenticeship system. This new standards based system of apprenticeship training and education was officially introduced in Ireland in 1994 encouraged by substantial funding from the European Social Fund. The European Social Fund, created in 1957, is the European Union’s main financial instrument for investing in people. It supports employment and helps people enhance their education and skills. (ESF-Ireland, 2007-2013).

1.2.2 Irish Standards Based Apprenticeship Educational System

The Programme for Economic and Social Progress (P.E.S.P.), which commenced in 1991 (Eurofound, 2009) provided the impetus for the new apprenticeship system to be adopted (Nyhan, 2009). A National Apprenticeship Advisory Committee (NAAC) was also established in 1991 to act as a steering committee (Nyhan, 2009) and was charged with drafting the standards-based curriculum in each trade (Field & O'Dubhchair, 2001). In 1991 the P.E.S.P. agreed that a new Standards-Based Apprenticeship system should be introduced and that to be recognised as a craftsperson, a person would have to attain the externally assessed National Craft Certificate as a compulsory requirement (CEDEFOP, 2009; Ryan, 2000). Since 1991, FÁS, the Training and Employment Authority in Ireland, in conjunction with the social partners and the education sector, has been engaged with this new system of apprenticeship. FÁS has the statutory responsibility for the control and organisation of all designated apprenticeship trades in Ireland under legislation conferred on it by the Industrial Training Act, 1967, and the Labour Services Act, 1987 (CEDEFOP, 2009). New statutory rules for the standards-based apprenticeship system were also introduced (Labour Services Act 1987 – Apprenticeship Rules 1997) (ESF, 1999).

The new Irish standards-based apprenticeship system requires apprentices to attend off-the-job training in block release rather than day release, and also requires aspiring participants to find employer sponsorship for themselves. The eligibility criterion for entry to apprenticeship is that candidates must be at least sixteen years of age and have a minimum of grade D in any five subjects in the National Junior Certificate or equivalent. However, some employers may also require additional minimum qualifications. There is no criterion for a required entry level of competence in science or mathematics. Where individuals do not meet the minimum requirements an employer may register them as an apprentice if they satisfactorily complete an approved preparatory training course and assessment interview, or if they are over eighteen years of age with a minimum of three years relevant work experience and satisfactorily complete an assessment interview. Only an employer who has been approved by FÁS may employ apprentices in their chosen occupation. The employer must register the apprentice with FÁS within 2 weeks of recruitment (FÁS, 2009a). Although there are no criteria for a minimum entry level of competence in mathematics or science, twenty-three of the twenty-six crafts listed by FÁS require either an understanding of mathematics to solve technical or scientific problems, an understanding and use of physics, or an accuracy in the use of counting, measuring and arithmetic (FÁS, 2010). The three exceptions to this are, the crafts of plastering, farriery and metal fabrication. It is not surprising then that some apprentices find it difficult to progress through their training and education when confronted with the mathematical modules within their course of study.

The standards-based or competency-based apprenticeship system is divided into seven phases (1 – 7). These seven phases should be completed consecutively over a period of approximately four years. Delays to this can be the result of a lack of available places in the FÁS training centres or the Institutes of Technology. Further delays in completing apprenticeship can arise from not meeting the requisite assessment standards required for progression from each phase, in which case a referral will be the result. If an apprentice is referred in a subject she/he will have to wait until the next time that particular assessment is repeated, which could typically be around three months later. If an apprentice fails to reach the required standard after three attempts, then, according to the rules of apprenticeship, the apprenticeship is terminated (O'Connor & Harvey, 2001).

Phases 1, 3, 5, and 7 of the apprenticeship are completed on-the-job, where employers are required to assess each apprentice to meet the required national standard of competence. Competence is defined as the application of skills, knowledge and attitudes to perform tasks or combinations of tasks to industrial and commercial standards under operational conditions (ESF, 1999). Employers then compile each of these phase results and submit them to FÁS. Most of the subject areas with the employer in the on-the-job phases of the apprenticeships are practically orientated with less emphasis on general education (Ryan, 2000). After successful completion of each of the on-the-job phases, apprentices are required to complete the off-the-job phases, 2, 4, and 6. Apprentices attend one of the FÁS training facilities for twenty weeks for phase 2 and one of the Institutes of Technology for ten weeks (eleven in some trades) for both phase 4 and 6 of their apprenticeship. Apprentices are paid a training allowance during these periods of off-the-job education.

During these phases of off-the-job training, apprentices are required to successfully complete both practical and theoretical assessments for progression to the next phase. It is during the off-the-job phases of the apprenticeship that any gaps in the apprentice’s education can be addressed. This should afford apprentices an opportunity to gain an understanding of aspects of their craft that they have not had the opportunity to experience on-the-job. Likewise, the on-the-job phases can also fill many of the craft training gaps that are not available within the off-the-job educational environments. In theory, all seven phases are designed to compliment each other and on completion apprentices awarded the National Craft Certificate should have a well-rounded level of competence and skill in their chosen craft. This certificate is placed at level six on the Irish National Framework of Qualifications, linking it to all other educational awards.

After decades of efforts by the Irish labour market policy makers a national regulated apprenticeship framework now exists (Nyhan, 2009). In his conclusion Ryan (2000) states that this development has moved Ireland away from the UK method to a more continental approach in three respects,

- The linkage of the apprenticeship to the education system.
- The development of social partnership for the design and administration of apprenticeship. (Employers, Trade Unions, Institutes of Technology, FETAC, FÁS)
- The adoption of a statutory framework to underpin the whole.
  (Ryan, 2000)

1.3 Standards Based Plumbing Phase Six Apprenticeship Curriculum

As this research study is based only on the phase six plumbing curriculum and the subject of applied calculations and mathematics in particular, a further in-depth analysis (section 1.3.1 below) of this off-the-job phase of the curriculum may help in the understanding of the rationale of this project. This may also assist in an explanation of why examination referrals often occur within this phase of plumbing apprenticeship. Within Chapter Two a further literature investigation shows a broader view in relation to the on-the-job, or workplace learning aspect of apprenticeship training, education and assessment (Velde & Cooper, 2000).

1.3.1 Phase Six Plumbing Curriculum Analysis

The phase six plumbing curriculum is based over an eleven-week period of off-the-job training and education. Over this eleven-week period student apprentices are required to cover five modules from which six practical assessments and two summative theory assessments must be passed, these are shown in Table 1.1 below.

Table 1.1: Phase Six Plumbing Assessment Schedule		
Assessment Title	**Description**	**Comments**
P 1: Arc Welding	Typically carried out in week 5 after 30 hours of guided practice	Practical Assessment: Module 1.
P 2: Oxy-Acetylene Welding	Typically carried out in week 10 after 87 hours of guided practice	Practical Assessment: Module 1.
P 3: TIG Welding	Typically carried out in week 9 after 16 hours of guided practice	Practical Assessment: Module 1.
P 4: Heating Systems Controls	Typically carried out in week 8 after 20 hours of theory and practice	Practical and Theory Assessment: Module 3.
P 5: Gas Soundness Test	Typically carried out in week 8 after 8 hours of theory and practice	Practical and Theory Assessment: Module 4.
P 6: Gas Spillage Test	Typically carried out in week 7 after 8 hours of theory and practice	Practical and Theory Assessment: Module 4.
T 1: Gas Installer Safety	Typically Carried out in week 11 after 44 hours of theory lecturers	Theory Assessment: Module 4.
T 2: End of Term Theory	Typically carried out in week 11 after 199 hours of theory lecturers	Theory Assessment: Modules 1, 2, 3, 4 & 5.

As can be seen from the above table, plumbing phase six apprentices have a very busy schedule both practically and theoretically over what sometimes may be effectively only a nine-week period when bank holidays, school-inductions, safety-inductions and examination periods are removed from the allocated eleven-week block. However, it is not until the curriculum for two theory assessments alone are analysed, that a true appreciation of the amount of learning and knowledge acquisition that is required from these students, within this timeframe, can be comprehended. The subject breakdown for these two theory tests (T1 & T2) follows in Tables 1.2 and 1.3. See also (Appendix 1) for FÁS Modular Plans.

Table 1.2: represents the amount of learning content that is in involved in the T1 summative assessment, which includes 61 key learning points from Module 4. The knowledge required for the two practical assessments P5 and P6 as listed in Table 1 above are also included in this module. To achieve a pass in the T1 assessment 66.6% is required and 77.7% required for a credit.

Table 1.2: Phase Six Plumbing T 1 Assessment Breakdown: Module 4

Unit Number.	Description	Comments
1. Safety, Legislation and Standards	4 Key Learning Points	5 Hours Allocated Lecture Time
2. Combustion	15 Key Learning Points	7 Hours Allocated Lecture Time
3. Flues and Ventilation	12 Key Learning Points	8 Hours Allocated Lecture Time
4. Installation	14 Key Learning Points	8 Hours Allocated Lecture Time
5. Pressure and Flow	8 Key Learning Points	8 Hours Allocated Lecture Time
6. Appliances	8 Key Learning Points	8 Hours Allocated Lecture Time
Summative theory assessment in week eleven – 18 questions – 12 to pass and 14 to achieve credit mark.		

Table 1.3: below, represents the amount of learning content that is in involved in the T2 summative assessment, which includes key learning points from Modules 1, 2, 3 & 5. To achieve a pass in this assessment 70% is required and 85% required for a credit. As can be seen, the pass requirement of 66.6% and 70% respectively for the T1 & T2 summative assessments is quite high.

Table 1.3: Phase Six Plumbing T 2 Assessment Breakdown: Modules 1,2,3 & 5		
Module Number 1. Thermal Processes and pipefitting		
Unit Number	**Description**	**Comments**
1. Related Safety	15 Key Learning Points	2 Hours Allocated Lecture Time
2, 3, 4 & 5 Arc, Gas and TIG Welding	Theory related to practice	In conjunction with practical workshop classes
Module Number 2. Advanced Pipe-work, Water & Waste Water Systems		
Unit Number	**Description**	**Comments**
1. Related Safety	8 Key Learning Points	2 Hours Allocated Lecture Time
2. Cold water for multi-storey buildings	15 Key Learning Points	5 Hours Allocated Lecture Time
3. Hot water for multi-storey buildings	10 Key Learning Points	5 Hours Allocated Lecture Time
4. Commissioning of hot and cold services	14 Key Learning Points	7 Hours Allocated Lecture Time
5. Cause and control of Legionella	10 Key Learning Points	6 Hours Allocated Lecture Time
6. Sewage Disposal	16 Key Learning Points	6 Hours Allocated Lecture Time
7. Rural Water Supply	9 Key Learning Points	6 Hours Allocated Lecture Time
8. Water Treatment	12 Key Learning Points	7 Hours Allocated Lecture Time
Module Number 3. Heating and Air Conditioning		
Unit Number	**Description**	**Comments**
1. Related Safety	8 Key Learning Points	2 Hours Allocated Lecture Time
2. Air Handling Units	14 Key Learning Points	4 Hours Allocated Lecture Time
3. Heating and Cooling Batteries	12 Key Learning Points	7 Hours Allocated Lecture Time
4. Solar Heating & Heat Pumps	17 Key Learning Points	10 Hours Allocated Lecture Time
5. Plumbing & Heating calculations	18 Key Learning Points	16.5 Hours Allocated Lecture Time
6. Boilers, Pumps, Pre-commissioning of Boiler-Houses and Heating Systems	23 Key Learning Points	12.5 Hours Allocated Lecture Time
7. Sectional Boilers	13 Key Learning Points	5 Hours Allocated Lecture Time
8. Heating Controls and Introduction to BMS Systems	23 Key Learning Points	20 Hours Allocated Lecture Time (Part of P4 Assessment)
9. Pricing and Estimating	13 Key Learning Points	6 Hours Allocated Lecture Time
Module Number 5. Heating and Air Conditioning		
Unit Number	**Description**	**Comments**
1. Related Safety	5 Key Learning Points	2 Hours Allocated Lecture Time
2. Fire Prevention Systems	17 Key Learning Points	7 Hours Allocated Lecture Time
3. Compressed Air / Medical Gasses	13 Key Learning Points	4 Hours Allocated Lecture Time
4. Steam Processes	18 Key Learning Points	27 Hours Allocated Lecture Time
5. Building Regulations	8 Key Learning Points	12 Hours Allocated Lecture Time
Summative theory assessment in week eleven – 20 questions – 14 to pass and 17 to achieve credit mark.		

Although Table 1.3, is very detailed it is still not exhaustive, because if all the ‘key learning points’ were to be fully expanded it would show the enormous amount of actual content within each unit. However, for the purpose of this contextual analysis the detail shown is quite adequate.

As can be seen also from Tables 1.2 & 1.3; over an eleven-week period each phase six plumbing apprentice has to gain enough skills to pass six practical tests and also then accumulatively gather enough information, notes and knowledge on thirty units (subject areas) within which there are approximately 372 detailed key learning points, to be tested in two summative assessments. I have become aware over the past number of years of the pressure that this amount of study material is placing on students, and the subsequent use of rote learning for theoretical subjects is very apparent.

With a standard phase six plumbing group, the above thirty units are typically delivered to students by up to six different lecturers on a weekly basis. The difficulty that students experience with this amount of content is also reflected in the lecturer who must deliver this curriculum in the allocated time for each module. Some of these units are proving difficult to deliver within the allocated timeframes. An example of this being Unit 3 within Module 5, where four hours are provided to deliver 13 detailed learning points. I believe that the pressure on lecturers to deliver this material is leading to an environment led by traditional lecture-centric teaching methods, and rote learning on behalf of the students. This bears a resemblance to earlier discussions regarding the national Junior Certificate, which was also acknowledged as driven by rote learning and examination pressures, rather than the promotion of real understanding and skills. This has become obvious to both a colleague and myself who have been providing extra nightly revision classes to student apprentices for the past number of years coming up to examination time.

The traditional method of teaching can be described as giving instruction by the lecturer and expecting students to be cognitively active but physically inactive, except for the taking of notes (Haghighi, Vakil, & Wetiba, 2006), thus viewing these students as passive learners (Gavalas, 2001). As discussed in the introduction to this chapter, this form of mathematical instruction is not succeeding in providing the skills that students need. It is now widely accepted that one way to gain the attention of students and make them interested in mathematics is to get them actively involved through hands-on activities (Haghighi, et al., 2006).

On a weekly basis these plumbing students are accumulatively gathering information and notes by attending lectures. This is leading to a gathering of an enormous amount of literature to be studied for the second theory (T2) summative assessment in the final week, where 70% is needed to pass and 85% required for a credit. As referred to in the introduction to this chapter, many students are being referred in this assessment each term. The referral figures in D.I.T for three terms of 2009 - 2010 were.

- Term (1) 2009/2010 – Plumbing T2 Assessment – Referrals 18.75%
- Term (2) 2009/2010 – Plumbing T2 Assessment – Referrals 50.0%
- Term (3) 2009/2010 – Plumbing T2 Assessment – Referrals 35.9%
  (D.I.T, 2010a)

There are customarily up to three maths questions in the above T2 assessment paper. The remaining seventeen questions are drawn from the twenty units covering approximately 293 key learning points. Many students who are comfortable with their mathematical knowledge and skills choose to attempt the maths questions, however, others skip them and try to obtain a pass from the remaining seventeen questions. If this is the case these students now need to achieve fourteen correct answers from a possible seventeen, which raises the pass mark up to 82.3% and 100% for a credit. Trying to achieve this high pass mark from such a wide study area (293 learning points) is I believe, where many referrals originate. Part of the reason for these referrals may also be linked back to earlier discussions regarding the level of mathematical competencies shown by students. From experience of marking these assessment scripts over the past number of years it is apparent that the maths questions are the most problematic to the majority of students. Whilst the majority of students pass this assessment, I believe there is a weakness in the depth of actual learning that is occurring over the course and in particular with applied calculations and mathematics.

My hypothesis on the above is that many of these units could be delivered using a more student-centred approach, enabling each student to design the particular topic into a typical building plan. Each of these subjects could then be formatively assessed over the duration of the course. This would mean the opposite to the above whereby students would be unloading a subject on a weekly basis having incorporated it into their design project. I believe that with each subject being related to a real life project and formatively assessed, it could also enhance and deepen the learning experience of students whilst also lessening the pressure and anxiety of the accumulation of a huge amount of end-of-term study material.

This small-scale research project used Unit Number 5, (Plumbing and Heating Calculations), within Module Number 3 of the FÁS plumbing curriculum as the single research subject. This was introduced and analysed using project-based learning to three consecutive groups of phase six plumbing apprentices as discussed previously. The broader rationale and motivation that has encouraged me to embark on this action research project, stems from a deep personal interest in improving my own teaching practice, and in authentic and innovative methods that can be used to enhance the learning experience of my students. The above information places this research in its specific context and also explains the rationale for the study.

1.4 Aims and Objectives of the Study

The specific aims for this study were based on the current apprenticeship educational paradigm and the increasing awareness of how a different learning and teaching approach may enable a better understanding of applied calculations and mathematics. This led to a desire to introduce and evaluate an alternative learning and teaching method in an effort to increase student motivation to learn independently and to a deeper level. These main aims which are which are also outlined below were pursued through the introduction of real life plumbing mathematical design projects, which incorporated tasks and problems for apprentices to engage with.

- To motivate students with the authenticity of the mathematical problems and projects
- To encourage a student-centred and deeper learning environment
- To enable students to establish a deeper understanding and awareness of applied craft calculations related to where they can be used in their line of work
- To provide students with a level of mathematical understanding and confidence that might encourage progression to further education
- To enable students to engage in self-assessment and peer-learning
- To provide students with a level of mathematical understanding and confidence to understand and tackle these problems within end of term summative assessments
- Help to contribute to the personal development of the students
- To reach the level of mathematical competence that would be expected of a qualified craftsperson

The aims of this project follow to some degree those recommended by the Department of Education and Skills 'Guidelines to Mathematics Teachers' and specifically focus on what student apprentice plumbers will be able to do with their mathematics and calculations in the future, and on their ability to recognise the power of mathematics and apply it appropriately (NCCA & DoE&S, 2002). On the whole it is hoped that with the introduction of PBL, students would have an overall picture of applied mathematics as a "system that makes sense" (NCCA & DoE&S, 2002) and that involves understanding individual concepts. In general, this system is concerned with knowing 'why', or so-called *relational understanding* (NCCA & DoE&S, 2002).

While it was outside of the authorisation of apprenticeship lecturers to change the curriculum or the assessments pertaining to it, different learning and teaching methods can be used where thought appropriate and worthwhile. This forms the foundation for the objectives of this research. The specific objectives of this action research study are outlined below.

- To determine if the introduction of a project-based learning (PBL) approach to applied calculations and mathematics for phase six plumbing apprentices, can improve their understanding and application of the mathematical elements of their curriculum.
- To determine if this approach is found to be useful, challenging and worthwhile to the mathematical learning of phase six student apprentices.
- To evaluate if the apprentices within this study group would find this method of learning and teaching worthwhile or applicable to any of their other subjects.
- To find out if the level of mathematical confidence of the students has been improved over the course of the study.
- To help students to feel personally involved in their own learning with a willingness to take ownership of their education.
- To encourage deep learning both inside and outside the college environment.
- To encourage an enjoyment of learning and to promote life-long learning.
- To give students a voice and listen to what they have to say.

It is thought that through the introduction of PBL, students should be able to apply their mathematical knowledge to work related tasks, develop an appreciation for mathematics, and also be able to analyse information presented in unfamiliar contexts.

Naturally all calculations and mathematics presented to the students within the study groups followed closely the scope of the FÁS curriculum, whereby students were not expected to carry out design calculations above this level.

1.5 Educational Research Ethics

Any research that involves people has the possibility of causing damage or harm (usually unintentionally) to those involved (Opie, 2004). Today research is a sophisticated endeavour, and there are many rules and regulations that we are obliged to follow (Lawrence, 2006). These rules and regulations are designed to protect all of the people who are willing to participate in the research that we conduct (Lawrence, 2006). Within the American Educational Research Association (AERA) ethical standards, there is also a reminder to educational researchers, that we should strive to protect people and maintain the integrity of our research (Howe & Moses, 1999).

There are also numerous international guidelines on the ethics of research using human participants including, The Nuremberg Code; The Declaration of Helsinki; The Belmont Report; International Ethical Guidelines for Biomedical Research Involving Human Subjects; and the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (Khanlou & Peter, 2005). Other sets of ethical guidelines are obtainable from organisations such as the British Educational Research Association (BERA), the British Psychological Society and the American Psychological Association (McNiff, Lomax, & Whitehead, 2003). No codes of ethical practice cover every eventuality but they do at least clarify the major issues in this complicated area (Bell, 2005).

One of the most important aspects of educational research ethics is unquestionably voluntary informed consent (McNamee, 2002). Following the horrific scientific experimentations on prisoners during the Second World War, the Nuremberg and Helsinki declarations laid out the inviolable principle of consent, assuring that the research participants had the right to be informed of the nature of the research and autonomously choose whether to participate in it (Hart, 2005; McNamee, 2002). All researchers should be aiming towards this principle of ‘informed consent’ which will require careful planning, preparation, explaining and consultation before any data collection begins (Bell, 2005), this study also followed these recommendations.

Medical research has been at the forefront of research ethics involving humans, with social research in general, and educational research in particular having generally pursued their lead (Howe & Moses, 1999). However, Howe & Moses (1999) further argue that educational research requires significantly changing the vocabularies and frameworks that the have been inherited through medical research ethics.

In a description of what qualifies as ‘human subjects research’ Lawrence (2006) draws from the Washington Department of Health and Human Services. They qualify this type of research as any research or clinical investigation that involves human subjects who are living individuals and from whom a researcher obtains data through intervention or interaction with the individuals or identifiable private information (Lawrence, 2006). Whilst all of the above is of high importance it is not enough to just show ethical awareness, but one must also act in an ethical manner (McNiff, et al., 2003)

1.5.1 Educational Action Research Ethics

In order to conduct this study to the best of my ability, I thought it necessary to fully understand, implement and accept responsibility for, the ethical principles of action research. Ethical issues are present in almost every aspect of action research (Bridges, 2003), around which this study is constructed. Ethics firstly enter action research as a set of principles governing the way in which the research itself is being conducted and in particular on the rights of the participants (Bridges, 2003). Action research involves more than simply conducting research with human participants, it is the researchers aim is to influence these participants (McNiff, et al., 2003). Anyone conducting action research must therefore be honest, fair and truthful at all times (McKernan, 1996).

> Because the activity of action research almost inevitably affects others, it is important to have a clear idea of when and where the action research necessarily steps outside the bounds of collecting information that is purely personal and relating to the practitioners alone. Where it does so, the usual standard of ethics must be observed: permissions obtained, confidentiality maintained and identities protected (Denscombe, 1998, p. 63).

In further discussion on action research ethics, Bridges (2003) emphasises that in the context of professional work, there is a level of responsibility to anticipate the consequences of one's actions whilst making some effort to observe and find out what they are and to modify one's actions in the realisation of that observation. This is very descriptive of the cyclical nature and intervention methods used in action research, where I believe ethical issues should be constantly reviewed. However, in action research, ethical responses to unanticipated events may be difficult to rehearse (S. Collins, 2004), as codes of ethics are normally situation specific, they are difficult to apply unless they are seen as applicable to particular circumstances (P. Gibbs, Costley, Armsby, & Trakakis, 2007). These new and unfamiliar situations should require us to extend our existing capabilities rather than revert to existing principles and set up formal codes (Small, 2002). Unanticipated ethical dilemmas are bound to continue regardless of the length of a checklist we may create to monitor ourselves (Malone, 2003). I would also support the view of Collins (2004), where he suggests that in action research, "moral discourse and moral reflection must be a central theme, and included in constant negotiations of authentic participation, power issues and language" (S. Collins, 2004, p. 349).

As reflection is one of the key elements behind action research I felt that I must be particularly careful in the compilation of this study, as a predetermined course of action cannot always be adhered to including ethical decision making (Jones & Stanley, 2008). Collins (2004) reinforces this view stating that action research does not allow for a very high level of predictability with the subsequent difficulty of being able to fully inform a prospective participant to gain their consent. Avoidance of harm is therefore difficult to guarantee in action research (S. Collins, 2004). The integrated practitioner/researcher role in action research is particularly difficult where access to information and consent for its use depends on a promise of confidentiality, or even anonymity (Tickle, 2002). With some of the concerns above in mind Gibbs, et al. (2007) encourage the use of reflective diary writing as a way for researchers to reflect and articulate the complexities of their approach to ethical issues in their particular study. The use of a reflective diary was therefore also thought appropriate in this research study both for ethical issues and for analysis of interventions and classroom experiences.

1.5.2 Educational Research Ethics within this Study

Ethical issues can arise during all stages of a research project, from design stage through to reporting stage (Hart, 2005). Many institutions including D.I.T have ethics committees that play an important gate-keeping role in ensuring that no badly designed, unethical or potentially harmful research is authorised (Bell, 2005). The D.I.T ethics committee guidelines state that they do not normally consider for approval, undergraduate and taught postgraduate research or dissertation projects (D.I.T, 2010b). Although this research falls under the latter part of this criterion, it was still in the interest of this research project to closely follow the guiding principles as recommended by the D.I.T ethics committee (D.I.T, 2010c). A letter for approval was also submitted to my Head of School fully outlining my research proposal and access to students prior to commencement of any project-work (Appendix 3).

Along with following the D.I.T ethical guiding principles this researcher also drew guidance from the 'Revised Ethical Guidelines for Educational Research (2004)', which is produced by the British Educational Research Association (BERA, 2004). It was also thought appropriate to refer to and comply with the standards of good practice as laid down in the Declaration of Helsinki (WMA, 2008) as advised in the D.I.T ethical principles and procedures (D.I.T, 2010c). Other useful resources that I have drawn further information and guidance from are the Australian Association for Research in Education and in particular their Code of Ethics (AARE, 2010). Also the Economic and Social Research Council (ESRC) in the United Kingdom and in particular their revised 2010 Framework for Research Ethics (ESRC, 2010).

At the start of this action research I thought it important to fully discuss with the participants, the rationale behind the project and the proposed methods that I intend to use. This took the form of an informal three-hour lecture/discussion on the whole plumbing curriculum and in particular on applied craft calculations and mathematics. I thought it also important to make all participants fully aware that in action research they are co-researchers and not just subjects to be studied. Along with them I am also part of this action research and any knowledge to be got from the research project is for the benefit of all involved. At the end of this discussion each participant was then issued with a written document further outlining the reasons for this research and how it is proposed to implement it (Appendix 4). Participants in the research were also fully informed that any questionnaires or focus groups that they were asked to have an input into were completely optional to each person and that they were free to withdraw from this at any time. This was further outlined in writing in a cover letter that preceded the first questionnaire document (Appendix 5). A reflective diary was also used to closely monitor any ethical issues or dilemmas that arose during the course of the research. Any written documents given to students were also to the best of my ability, written in a language that was easily understood by the participating group.

As focus groups were the preferred method of interviews in this research project, six participants were chosen from the class register. These six participants were then asked if they would be willing to take part in a focus group and discuss their thoughts and feelings on the research project. On agreement to take part in the focus group each participant was then issued with a consent form, five days before the discussions began. This consent form was again preceded with a fully detailed document outlining the research that is being undertaken, the reasons behind it and the confidentiality guaranteed (Appendix 6).

I feel that the above efforts of complete transparency and authenticity along with the detailed information issued to both active and passive participants complies with sections; 10 & 11, *Voluntary Informed Consent,* section 13, *Right to Withdraw*, and section 23, *Privacy*, of the BERA ethical guidelines discussed previously. In relation to section 20, *Incentives*, of the BERA guidelines, it was also thought appropriate to withdraw myself from the marking of any examination scripts or assessments relating to the particular group of students who are participating in this research.

As this research was run over three apprenticeship terms with three different groups, all of the above ethical procedures and standards had to be repeated, maintained and sometimes modified each time. While the school is identifiable in this research each particular group of students are not and in particular each participant has complete anonymity in this thesis.

In conducting this research I have found it essential to satisfy myself that I have done everything possible to ensure that my research is conducted in a way that complies with my own ethical principles and also those of the local and international guidelines mentioned above. I have strived to make no promises to either participants or my institution that cannot be fully honoured. Further to this, no information or data collected during the course of this research will be misinterpreted or concealed in any way. Having taken all of the above into consideration I believe that this research is being conducted to the highest possible ethical standards that encourages and supports personal development and brings about no harm to any individual, organisation or institutional processes.

Chapter Two

Review of the Literature

2.1 Introduction

This research study was attempting to establish, *if a deeper understanding and application of building services applied calculations and mathematics could be achieved through the implementation of project-based learning within apprenticeship education?* Before attempting to answer this question it was thought necessary to firstly review the literature in an effort to establish if observations made regarding the difficulties that student apprentices' are experiencing with mathematics, along with their lack of basic mathematical comprehension and knowledge, was reflected throughout further education in general. From here it was considered essential to further search the literature in an effort to gain an understanding of why mathematics seem to be problematic for so many apprentices and students in further education who have been exposed to mathematics education from an early age.

This has lead to an examination of the literature relative to the teaching and learning of mathematics from second level to third level education both nationally and internationally. Apprenticeship education was then reviewed in detail where the importance of both on and off-the-job training is discussed from both a general and mathematical viewpoint. This literature review was also framed by a discussion of the context and motivation for the study, which is the introduction of project based learning within the mathematical education of plumbing apprentices in an effort to improve their understanding of this subject. Further investigations through the literature also reveal thoughts on action research as a platform for the introduction of this method of mathematical learning and teaching.

2.2 Training and Education with Particular Reference to Apprenticeship

2.2.1 Previous Mathematical Experiences

The difficulty that many apprenticeship students have with fully understanding craft calculations and mathematics in general may stem from their first and second level educational experiences. In a study of second-level classroom practices in Ireland, Lyons (as cited in Breen, Cleary, & O'Shea, 2009) found that teaching was strongly didactic, and was especially so in mathematics classes. They found that teachers were under pressure to cover the syllabus to prepare for state examinations, which led to a reliance on drill and practice. "National and international studies (The Chief Examiners Report, 2000; Third International Mathematics and Science Study, TIMSS; Programme for International Student Assessment, PISA) suggest that Irish mathematics classrooms are largely traditional, where exam-focused teaching relies on recall and routine procedures" (Hourigan & O'Donoghue, 2007) and where pupils rely on rote memory as an alternative to understanding (Engineers-Ireland, 2010). PISA's idea of mathematical literacy is especially relevant for students studying Science or Engineering (Breen, et al., 2009).

Furthermore, Breen, et al, (2009) also found that teachers had a profound influence on students' perceptions on mathematics, where negative attitudes and even 'mathematics anxiety' were associated with teachers going too fast. Speaking on mathematical education in secondary schools as far back as the 1960's (English, O'Donoghue, & Bajpai, 1992, p. 751) agree that the "complexity of some structures together with the excessive speed of their presentation did not provide a recipe for success with all students". Developing this argument further (English, et al., 1992), state that changes made to the Irish secondary school mathematics curriculum in the 1970's served only a small academic elite group of students.

Abroad, the same problem seems also to exist, where in 1975, in the light of a discussion on the teaching of mathematics in the United Kingdom, a working party was formed to consider the general problem of the mathematics required by school leavers who wish to enter industry as craft and technician apprentices (1977-Report). Within their report they state that many people in industry and in further education have expressed great concern with the decline in mathematical performance shown by the sixteen year old school leavers who apply for craft and technician apprenticeships. This working group had “vociferous criticisms from so many different quarters of the engineering industry of the effectiveness of mathematics teaching in schools” (1977-Report, p. 486). In the United States the problem also seems widespread with school leavers. During the late 1980’s, Motorola reported that only 20 per cent of job applicants passed a simple seventh-grade English test or a fifth-grade mathematics test (Armstrong & Kleiner, 1996). Their report also concludes “the majority of those who do manage to complete high school do not have the skills to succeed in today’s workplace”.

Reporting from their findings on ‘recent changes’ to the Irish Intermediate Certificate during the 1990’s, (English, et al., 1992) described these moves as being an ‘inadequate response’, which will continue to ensure that many students will flounder and understand little with regards to mathematics and schooling. Furthermore, these students will find it impossible to learn more mathematics if proved necessary in the future (English, et al., 1992). The current situation seems not to have changed, where there is consensus among university mathematics lecturers in Ireland that mathematics grades achieved in second level state examinations today show grade depreciation compared to ten years ago (Hourigan & O'Donoghue, 2007). This lays weight to earlier discussion regarding the apprehension that some students suffer with regards to mathematics.

In their article entitled ‘Cognitive Apprenticeship’ (A. Collins, Brown, & Newman, 1987, p. 4) also argue that during schooling “the emphasis is on formulaic methods for solving ‘textbook’ problems, or on the development of low-level sub-skills, where few resources are devoted to higher-order problem solving activities that require students to actively integrate and appropriately apply sub-skills and conceptual knowledge”. Oldham, (as cited by Breen, et al., 2009) also remarks that such beliefs could lead to lessons in which the ‘lower-order skill is valued above the higher-order, the procedural above the conceptual, and the de-contextualized above the applicable’. Hershkowitz et al, (as cited in Nunokawa, 2005) also stresses that newly constructed knowledge is rather fragile and it needs to progressively become more consolidated through being recognised in further activity.

Whilst describing students mathematical beliefs, intuitions and past experiences in trying to make sense of the world Schoenfeld (1987), suggests that one such belief that may result is that classroom mathematics is formulaic, non-negotiable, and not related to the real world. Additionally he emphasises that many students don't feel good about maths, largely as a result of the way they have been taught.

> We train our students to become proficient in answering questions they will never be asked again. The harm we inflict by this sort of skill, since they never really understood the meaning of the answer they gave, they will be unable to answer questions, which do come up. Breaking this cycle is one of the most important pedagogical challenges in mathematics education (Artemiadis, 2009).

In their study entitled '*What Irish pupils say about mathematics*' (English, et al., 1992, p. 749), state that "an over-emphasis on procedures and techniques in the Irish context has led to a neglect of the 'pleasure and aesthetic side of mathematics". A survey of Irish mathematics teachers carried out in conjunction with the Organisation for Economic Co-operation and Development's (OECD), Programme for International Student Assessment (PISA) 2003, also found that many teachers focus on skills and learning objectives assessed in examinations, rather than those that are not (Breen, et al., 2009). In their most recent study PISA report that for most countries, performance in mathematics remained broadly unchanged between 2003 and 2006 (PISA, 2006). As a result, conceptual and problem-solving knowledge acquired in school remains largely un-integrated or inert for many learners (A. Collins, et al., 1987). Breaking this cycle I believe is also another major challenge within education.

These difficulties with mathematical competence are not only confined to Ireland but are also present worldwide and to varying degrees (Engineers-Ireland, 2010). Governments and education sectors internationally, are also concerned with the consequences of the 'mathematics problem'(Hourigan & O'Donoghue, 2007), where growing consensus exists that the inability of students to successfully make the transition to third level mathematics education Tickly and Wolf (as cited in NCCA, 2005) lies in the substantial mismatch between the students second level mathematical experiences and the subsequent third level courses which include mathematics. Mathematics Departments within the Irish Third Level Institutions have also expressed dissatisfaction with the ability of entrants since the mid – 1980's (Hourigan & O'Donoghue, 2007).

From the above literature analysis it appears that much is lacking in second level mathematical education from where the majority of our students come. In their discussions (Breen, et al., 2009) also conclude that the Irish education system does not seem to be achieving its aim of instilling the skills required for mathematical literacy, as defined by the OECD (Appendix 7).

Because of the national obsession with the state examinations, i.e. the Leaving Certificate, many teachers see their primary function as preparing their pupils for this vital examination. "Unfortunately in doing so, teachers are narrowing such pupils' future potential, as exam-driven practice generally results in regimental thinking, with limited problem solving ability". (Hourigan & O'Donoghue, 2007, p. 473). This then leaves third level lecturers in the unenviable position of trying to educate students with an expected level of previous mathematical competence, which is often not adequate.

A report in the United Kingdom entitled *Measuring the Mathematics Problem* presented evidence of a 'serious decline of students' mastery of basic mathematical skills' (Hirst, Williamson, & Bishop, 2004). Since the publication of this report the authors believe that the situation has not improved and is causing acute problems for those teaching engineering mathematics. In order to overcome this particular difficulty, I personally find myself having to initially teach applied calculations, and mathematics in general from the most basic level first in an effort to bring all students up to the required standard together. This seems also to be the trend internationally where a growing number of institutions have to accommodate these mathematical 'at-risk' students by setting up short term strategies to offset the effects of their second level mathematical under-achievement (Hourigan & O'Donoghue, 2007).

Higher education has been aware for some time of the 'mathematics problem', which has arisen due to a rapid decline in students' mathematical skills between 1990 and 2003 (Hirst, et al., 2004). This situation is on-going and academic departments will need to be aware of developments and adjust their teaching strategies to provide the best possible learning experience for incoming students (Hirst, et al., 2004). This could also include a more student centred approach such as project or problem-based learning within apprenticeship education. Also speaking in favour of project-based learning Barron, et al., (1998) argue that if curriculum changes are not made carefully, we risk a political backlash that favours back-to-basics and rote learning over authentic inquiry (Barron, et al., 1998). Grimson (2002) also reports that there is widespread agreement that courses should promote problem solving abilities, self-directed learning and life-long learning within engineering education. The implication is that teachers need to move away from simply teaching basics, to the use of problem or project based learning, in an effort to encourage students to tackle real-world problems (Grimson, 2002).

As can be seen from the above literature review relative to prior mathematical experiences, it appears that the mathematical problems that we are witnessing with student apprentices seems as problematic generally within the tertiary educational system, (NCCA, 2005), (Hourigan & O'Donoghue, 2007), (Hirst, et al., 2004). The National Council for Curriculum and Assessment in Ireland (NCCA, 2005), has raised many of the issues mentioned above in a publication entitled *Review of Mathematics in Post Primary Education,* as a prelude to reform of the system in Ireland.

> As the present examination situation seems to dictate the mode of teaching and learning employed by most teachers and pupils, one suspects that the alteration of the mode of assessment to include project work, for example, would foster the development of problem-solving and higher-order thinking skills (Hourigan & O'Donoghue, 2007).

In their most recent report published in February 2010 and concerning the approach to mathematical and applied mathematical education at second level in Ireland, Engineers Ireland outline the importance of this subject as being an essential everyday life skill (Engineers-Ireland, 2010). This report goes further to mirror many of the views already expressed and to make such recommendations as listed below.

- Support for ‘Project Maths’ as discussed in section 1.2 above.
- Ensuring that maths teachers are adequately qualified to teach.
- Integrate applied mathematics into new approach (problem-solving in engineering and other technology courses).
- Give more time to the teaching of mathematics.
- Investigate failure rates at ordinary level Leaving Certificate as these high failure rates are having a serious impact on the quality of mathematical competency of those entering third level institutions.

It is the introduction of such problem-solving project work through this action research study, into the mathematical education of apprentices, which frameworks the rationale and motivation for this thesis.

2.2.2 Apprenticeship education

“It is only in the last century, and only in industrialised nations, that formal schooling has emerged as a widespread method of educating the young. Before schools, apprenticeship was the most common means of learning, used to transmit the knowledge required for expert practice in fields from painting and sculpting to medicine and law” (A. Collins, et al., 1987, p. 3). A definition of apprenticeship nowadays generally “denotes a formal, structured programme of vocational preparation, sponsored by an employer, that juxtaposes part-time off-the-job training and work experience, leads to a recognised vocational qualification at craft or higher levels, and takes at least two years to complete and fully four in Ireland” (Ryan, 2000).

It is considered that off-the-job phases of the Irish standards based apprenticeship are an invaluable resource for both employers and apprentices alike. In other systems of apprenticeship such as in Australia it is possible to have 100 per cent on-the-job traineeships (i.e. where the ‘off-the-job’ portion is delivered on the job) (Smith, 2002). This shift in emphasis away from institutionalised to workplace learning or ‘informal learning’, Lee (as cited in Onstenk & Blokhuis, 2007) has occurred despite the fact that the nature of learning at work is not clearly understood (Harris, Willis, Simons, & Collins, 2001).

This distinction between formal and informal education may be unhelpful because it implies the superiority of learning which takes place within educational institutions over workplace learning (Fuller & Unwin, 1998). This research study makes no such claims or comparisons. There has been some research into the nature of this type of informal learning; e.g. cognitive apprenticeship (A. Collins, Browne, & Newman, 1989); everyday cognition Rogoff & Lave; situated learning Resnick; (as cited in Brooker & Butler, 1997). The small amount of research into the informal setting has relied on the social, interpretivist and social constructionist models of learning, whereas research into the formal setting has been dominated by the individual psychology of learning (Brooker & Butler, 1997). In today's increasingly complex world, people need to continually learn in order to adapt to life's circumstances and the environment, Galbraith (as cited in Sparks, Ingram, & Philips, 2009).

2.2.3 On and off-the-job training and education relationships

Reports from a study by the Technical and Further Education (TAFE) Consortium in Australia state that, although employees overwhelmingly preferred learning on-the-job, they also cited inhibiting factors to learning, such as being pressurised by the demands of production and the unpredictable quality of workplace trainers in terms of ability to impart knowledge and skills (Harris, et al., 2001). Findings also indicate that where production is valued over learning, a number of effective learning processes are underdeveloped for apprentices (Brooker & Butler, 1997). Within such a system in South Australia, Misko (as cited in Smith, 2002) found that only between 12 and 15 per cent of on-the-job trainees were given regular allocated time during working hours to do the off-the-job components of their traineeship. From research carried out in the United Kingdom, Kemp (as cited in Smith, 2002), highlights similar problems in work-based modern apprenticeships, with many providers of work-based training being rated inadequate by the official inspectorate (Ryan, et al., 2006). Ryan et al, (2006) also highlight that few employers in any sector support an extension of the educational content of apprenticeship programmes, whether technically or generally oriented. Concluding their study of apprenticeship workplace learning Brooker & Butler, (1997) question the degree to which apprentice training in the workplace promoted effective learning in the clash between the learning goal and the production ethic. Their study also found that "once an apprentice became productive, the emphasis on learning was diminished. In their related study of apprenticeship learning within the Technical and Further Education Colleges (TAFE), (Butler & Brooker, 1998) report that in apprentices' minds the absence of production pressure off-the-job, creates a formal learning environment in which there was more freedom to learn. Off-the-job training should be available particularly where companies do not possess significant experience and skills in training (Smith, 2007).

In Ireland all registered apprentices must attend a recognised provider for all of their off-the-job phases (FÁS, 2009c). This is in an effort to ensure that a national consistency of quality can exist within the delivery of the curriculum. Within a questionnaire from an action research project carried out among student apprentices in the United Kingdom, it was this quality of 'teaching and learning' that was placed first as their most important motivating factor (Maynard & Smith, 2004). As can be seen from the above, it is imperative to apprenticeship education that a balance exists between their 'on' and off-the-job training. "Where young people are employed it is essential that what they are learning off-the-job should relate to and integrate with what they are doing on-the-job" (Huddelston, 1998, p. 288). It is therefore vitally important that apprentices receive the most dedicated and up to date learning, teaching and assessment techniques possible, within an encouraging environment, while attending off-the-job phases of their learning curriculum. Colleges can provide realistic learning environments for apprenticeship training through practical exercises and theoretical project-work, and also offer expertise in the area of assessment, particularly in the training of workplace assessors (Huddelston, 1998).

Previous to teaching I was a senior contracts manager for fifteen years within a large building services engineering company where apprenticeship recruitment and training formed part of my duties. As part of this remit I was required to monitor the progress that apprentices made through the various on and off-the-job training phases and also assess their suitability for inclusion on certain contracts. Apprentice training schedules also had to be compiled in order to make sure that learners were given as much variation in training as possible, and that they complied with current FÁS curriculum assessments. The result of these assessments was then compiled and submitted to FÁS, for the particular on-the-job phase to be complete. This process was carried out in order to comply with the company's 'commitment to quality' strategy. In the findings of their research paper, Fuller and Unwin (2007) also indicate that effective apprenticeships are strongly associated with a sustained organisational commitment to apprenticeship. “This approach is manifested through the development of programmes which ensure that apprentices participate in a wide range of co-ordinated and progressive work and learning opportunities” (Fuller & Unwin, 2007, p. 447).

Although there are difficulties in assessment in any context, in a busy commercial company it is sometimes very complex to assess on-the-job learning (Harris, et al., 2001) whilst also maintaining production levels (Ryan, 2004). “There is also a general acknowledgment that production takes precedence over learning at work, Evans (as cited in Smith, 2002). There are also some employers who simply use apprentices as additional labour and employ them on tasks of a repetitive nature (O'Connor, 2006). This can lead to inadequate on-site experiential learning that is an important aspect to craft development. There is also a lack of monitoring of apprentices on site by FÁS, which is perceived by employers, and apprentices to be a defect in the structure of the standards based apprenticeship (O'Connor, 2004). In a small-scale survey of apprentices and employers in Ireland (Field & O'Dubhchair, 2001) also believe that there are grounds for doubts concerning assessment of on-the-job training. In a research survey of Irish employers it was reported that eighty per cent of those interviewed experienced difficulty in assessing the apprentices on-the-job phases (O'Connor & Harvey, 2001). From my own managerial experience I would agree that the pressures of a busy construction business make it difficult at times to monitor all apprenticeship training and assessment. However, as with all assessment, feedback between apprentices and their supervisors or managerial staff is important as both can then address any learning gaps that have become apparent in either their practical skills or theoretical knowledge.

The British Youth Training scheme also highlights the difficulty of ensuring sound training practices amongst employers of youth trainees (Smith, 2002). This does not necessarily mean that the actual work-based training element of the apprenticeship is poor, provided that the apprentice receives proper supervision and variety of appropriate tasks (O'Connor, 2006). In an action research survey of modern apprenticeships carried out in the United Kingdom, one approach was to increase the number of assessor visits to the workplace. Employers welcomed these visits and believed they encouraged learner motivation. The outcome of this research project was that Foundation Modern Apprentices achievement improved by 28 per cent compared to other learners and Advanced Modern Apprentices achievement rose by 10 per cent (Maynard & Smith, 2004).

It can be seen that for a streamlined progression to be made throughout a standards based apprenticeship, there must be a strong educational relationship between the 'on' and off-the-job phases. Co-ordination is essential to ensure that training results in qualifications that are widely accepted by employers (Toner, 2008). This can be very difficult to achieve without full commitment and cooperation between employers, educational institutions and apprentices. They must work closely together to ensure that the curriculum meets the needs of both students and employers (Velde & Cooper, 2000). Casey, (as cited in Harris, et al., 2001) also concludes that both on-the-job and off-the-job partners need to 'clarify their respective roles in the provision of a supportive learning environment'.

2.2.4 Apprenticeship mathematical learning and teaching

Throughout my own teaching experience it is evident that many apprentices entering third level institutions for their off-the-job training, suffer similar mathematical anxieties, misconceptions and problems as previously discussed. However, within the current FÁS plumbing curriculum there are mandatory core sections relating to heating and plumbing calculations and now also included are pricing and estimating subjects (FÁS, 2006a). There are also other subjects where calculations form necessary components such as in Domestic Gas Installations and Commercial Steam Systems. Plumbing apprentices therefore need to gain an understanding of these calculations not only for examination purposes but also to use as part of their craft in real working situations.

The Chartered Institute of Plumbing and Heating Engineering (CIPHE), in association with industry partners Summit Skills have developed a Minimum Technical Competency (MTC) document, to set out the basic indicators for training, experience and knowledge to ensure that an individual or organization, working in the building services sector, has the appropriate skills to undertake work within a Competent Person Scheme (CPS) of the Building Regulations (Appendix 8). Part of the entry requirement to MTC is an NVQ level 3 benchmark, that includes relevant system design elements, such as pipe sizing, and heat loss calculations, that would be expected of a competent person (CIPHE-SummitSkills, 2007). As there are many members of the CIPHE in Ireland and also many standards used within the Irish building services industry which require the craftsperson in question to be a ‘competent person’ (i.e. IS 813, 2002, Domestic Gas Installations) (NSAI, 2002, p. 8) this could also have an impact on many plumbers in this country. It is also a fact that the Irish apprenticeship system is now fully based around ‘standards’ and ‘competence’.

Evidence of training and assessment alone are not sufficient to prove that an individual has the skills to plan, install, and commission work in compliance with the Building Regulations. Therefore, adequate experience, skills and knowledge and the ability to apply them in the workplace are an essential part of the entry requirements for competent person scheme registration (CIPHE, 2009b). Mathematical skills will also be necessary for any further educational progression and development. The CIPHE offer training guidelines to people wishing to enter the plumbing trade as apprentices. One of the most frequently asked questions is centred on the test required to get onto a plumbing course. The institute’s response to this is:

> This is usually a general test to gauge your ability in mathematics and problem solving. The reason this is set is because some people enrolled on plumbing courses find it difficult to get to grips with the calculations that arise in the course work. Plumbing courses have a high drop out rate because people underestimate how difficult the course is, colleges want to ensure potential students have the ability to succeed (CIPHE, 2009b).

The Sector Skills Council for Building Services Engineering (Summit Skills) in the United Kingdom also list problem solving as one of the mandatory key skills to be acquired for plumbing apprentices (Summit-Skills, 2009). “The craft apprentice needs to learn the mathematical procedures in a usable, applicable way” (Technical-Education, 1961b). “Understanding mathematical tasks requires constructing meanings and doing interpretive work, rather than merely performing routine manipulations" (Hung, 2000, p. 64). A career in plumbing and heating calls for a dedication to lifelong learning, as the rate of technological advancement is rapid, an understanding of mathematics and science is also vital (CIPHE, 2009a). Because formal lecturing techniques, are in the main, ineffective with craft classes (Mills & Treagust, 2003), the tendency is to blame the subject of mathematics for the learning difficulties or the student for lack of talent (Technical-Education, 1961b).

One of the primary purposes of apprenticeship is to develop vocational practice where the project-based nature of the work requires a project-based approach to education and training (Guile & Okumoto, 2007). Because of previous bad mathematical experiences as described earlier, I have observed many apprentices who completely shy away from applied mathematics and even try to get through examinations without attempting any of the mathematical questions. This is really of no benefit to either the apprentice or their employer, as expectations of their training and competence will usually mean they will be asked to perform calculations on site at some stage in the future. Inability to carry out these tasks can be a cause of embarrassment for the apprentice and may also lead to a lack of faith by employers and the public in the quality of their training, ability and certified achievements. (Field & O'Dubhchair, 2001) even express concern regarding the reliability of the National Craft Certificate as a basis of judgements by any employer.

I believe that when apprentices are faced with the same mathematical learning and teaching techniques that failed them in secondary school that they are left with little choice but to practically ignore the subject altogether. This in turn can lead to anxieties and referrals in examinations, as the required 'pass' percentage must now come from fewer questions attempted. Within apprenticeship education the main reason for delay in completion is difficulty in completing tests/exams (Conway, 2007). Even when teaching applied mathematics it is sometimes argued that many, so called applied mathematicians all too often do not apply mathematics to anything in particular (D. P. Wilson, 2009). Although there is a notional appeal of relevance to an application for the equation under study, often mathematics are presented with esoteric and obscure maths (Artemiadis, 2009), which are not accessible to stakeholders in the application of the problem (D. P. Wilson, 2009). Poorman, (as cited in Onstenk & Blokhuis, 2007) shows in analysing extensive case studies how often only spurious relationships exist between assignments by the vocational school and actual work tasks. “The most fundamental and critical shift required in developing students’ personal mathematics epistemology, is for them to appreciate that mathematics is concerned with meanings and not just symbols” (Hung, 2000, p. 64). This is especially true for apprentices who should be able to apply their mathematical skills directly to their craft.

I consider that it is only with the intervention of learning, teaching and assessment techniques that engage students with links to real world problems that learners will begin to embrace mathematics and find significant value in the acquisition of a new knowledge. The application of craft science demands and encourages a personal effort to learn and to understand. It needs experiments and demonstrations supported by individual and group project work, where the teacher is directing the active learning rather than giving facts from textbooks in lecture form (Technical-Education, 1961a). In a survey of automotive apprentices carried out in the United Kingdom, their mathematical coursework was often considered in an engineering context; here students were applying their skills in calculations from the classroom to their projects in the workshop. All of the apprentices stated how helpful this practical application was in terms of assisting them to understand, appreciate and remember mathematics from their calculations class (Dickson, 1979). Companies must realise that its workforce, must receive proper training to transfer adequately and effectively what has been learned in the classroom to the workplace (Armstrong & Kleiner, 1996). I believe that schools and educational institutions also need to fully realise this objective. Apprentices should also be able to see the relationship between their workplace experience and their programmes of study as part of a whole (Onstenk & Blokhuis, 2007).

Describing how mathematics should be taught to engineering students (Andrié, 1985), argues that mathematics cannot be taught in a stereotyped and theoretical way, but must have relevance to applied engineering. Within a national research survey of schools, colleges and universities within the United Kingdom, students complained that mathematics was being taught without any bearing on engineering (Crowther, Thompson, & Cullingford, 1997). They recommended an ideal solution would be to employ an applied mathematician with an engineering perspective rather than a pure mathematician with little or no engineering interests (Crowther, et al., 1997). Andrié (1985) also makes the point that where students lack motivation an application-orientated method of teaching is necessary to give students the desired background. Fluency and confidence in the use and knowledge of mathematics comes with repetition and practice but a deeper understanding comes with experience of transferring concepts and principles to new contexts and applications (Hirst, et al., 2004). I believe that this convincingly reflects what project based learning may provide to learners.

There are twenty-six trades in which apprenticeships can be taken in Ireland and within each there are applied calculations or arithmetic forming part of the learning requirement (FÁS, 2009b) (Appendix 9). As each of these twenty-six crafts is now qualifying through a standards-reached system, it is imperative that apprentices receive the proper education while engaged in off-the-job training. This is highly important, as referrals in national trade examinations will mean a delay in an individual's journey through these seven phases. This in some instances can lead to a complete dropout of the apprenticeship system altogether (Conway, 2007).

I have found from teaching and marking of assessment papers (both formative and summative) that there is a distinct lack of understanding when it comes to the subject of mathematics and where they can be applied to their craft. While mathematics can be taught quite effectively, and problems worked out by students within the classroom, there is a misconception that these calculations cannot be related to, or useful for, their chosen craft. I have also noticed that there is often a lack of confidence in their mathematical ability, even with phase six students who have previously been exposed to applied mathematics in phase two and phase four of their apprenticeship. Confidence in one's ability to learn mathematics has also been found to have a strong positive correlation with mathematical achievement (Breen, et al., 2009). The reasons for this I believe are evident from previous mathematical experiences, where learning and teaching techniques, as discussed previously, are not proving appropriate for an adequate understanding of the subject. In a research study carried out in the United States, teachers' self confidence as mathematics teachers was also significantly associated with their students' self confidence as mathematical learners (Stipek, Givvin, Salmon, & MacGyvers, 2001).

The practical application of mathematics is also of the essence in engaging and motivating students to embrace and understand applied mathematics. Effective teachers 'involve' students in learning as apprentices, they work alongside students and/or set up situations that will cause students to begin to work on problems even before fully understanding them (A. Collins, et al., 1989). In addition, teachers are encouraged to provide students with varying kinds of practice situations before moving on to more challenging tasks, allowing an understanding that surpasses the use of formulas. Collins, et al, (1989) also make the point that the reason Dewey, Papert, and others have advocated learning from projects rather than from isolated problems is, so that students can face the task of formulating their own problems, guided by the 'interesting' phenomena and difficulties they discover through their interaction with the environment. Students should engage in mathematical activity with confidence and enthusiasm, and teachers should use assessment strategies that focus on understanding rather than on right answers (Stipek, et al., 2001). To give an apprentice the added skill and confidence to understand and use calculations within their working life, can I believe, help to achieve the desired level of craftsperson, to which a standard's based learning paradigm is aspiring to produce.

The negative impact is more pronounced if the knowledge and skills required to do well on a test are for the most part ones relating to the recall or recognition of factual information, rather than the ability to synthesize data or apply principles to new situations (Kellaghan, Morgan, Fitzpatrick, & Millar, 2002). Also it is often claimed that a curriculum that contextualises knowledge to the workplace increases the scope for learning and motivation (O'Connor, 2006). It is interesting to note that Collins, et al, (1989), also reinforce this view when they argue that a critical element in fostering learning is to have students carry out tasks and solve problems in an environment that reflects the uses to which their knowledge will be put in the future. This statement I believe also advocates the use of project-based learning.

Apprenticeship education will invariably need to include learners being introduced to trade calculations and mathematics within their line of work. Through my previous experience in management this has led to apprehension among some apprentices when asked to carry out these calculations on site. Most of the time apprentices could not relate the mathematical theory learned in college to the on-site practical situation.

Whilst the underpinning theory, science and mathematics learned in the Institutes of Technology is crucial to the whole learning process, it is the application of these competences in real life situations on-site that is one of the hallmarks of high-quality craftsmanship (O'Connor, 2006). For this reason I believe that the applied mathematics and calculations taught in college should directly link to, and be a reflection of, what a craftsperson is expected to perform as part of his or her duties in the workplace. Apprenticeship education including applied mathematics should also continue to grow and prosper within the on-the-job phases of their apprenticeship. However, this needs careful committed monitoring, assessment and proper supervision for suitable progression to be made.

I have done a lot of work both on the design and delivery of some of the modules on the D.I.T. Advanced Plumbing and Mechanical Services course, DT151, that provides a route of progression for apprentices (D.I.T, 2009). It is evident from this course, which is entirely project based, that a deeper understanding of applied mathematics is required in order to design a workable mechanical building services system. I have found that many newly qualified craftspeople holding a National Craft Certificate entering this course, are not fully equipped with the general craft applied mathematical design knowledge needed to be integrated into a practical design project. During interviews held to enrol students for this course I have often be asked 'at what level are the mathematics on this course', as there seems to be a particular lack of confidence in this area alone. I have never been asked as to what level any of the other subjects on this course (of which there are 12) are set at.

During the initial few weeks of my modules on this course, I always find myself having to go back over basic calculations which should be second nature to students who have just completed a standards based apprenticeship and who now hold a National Craft Certificate. However, when students take these calculations on board this time, and then use them to design their own projects, their understanding and knowledge of the process advances to a much deeper level. This is evident during interviews with students about their project design where they now show complete confidence and proficiency and a willingness to debate, argue and defend in depth, their newly discovered mathematical abilities. Many of these students progress to a level where I can also learn from them.

I feel that apprentices finishing their training and obtaining a National Craft Certificate should also have the confidence in their ability to understand and use mathematics in industry or without fear of progression into higher educational courses. This confidence may be enhanced by the introduction of learning and teaching techniques that foster understanding, use practical applications and projects to mobilise their knowledge, and construct new knowledge (Grugnetti & Jaquet, 2005), whilst also promoting enjoyment of the subject of applied mathematics. Project based learning can in my opinion also be utilised in this respect.

2.2.5 Apprentice Educational and Career Progression

The plumbing industry holds diverse career paths, good wages and the opportunity for individuals to run their own business. Many plumbing apprentices progress to more senior positions in the industry, such as supervisors, foremen or project managers (O'Connor, 2006) and even on to design, consultancy, teaching and management, making the plumbing and heating industry a career with a future (CIPHE, 2009a). Qualifications and education gained from apprenticeship can often lead to apprentices re-entering the mainstream educational system on a part time or full time basis. Ryan et al, (2006) reinforces the view, that the apprenticeship system can potentially make apprenticeship part of a ‘vocational ladder’ within the education system. In the United Kingdom, within the 2004 Tomlinson report, there is also a proposal for “strengthening the vocational options available to young people, including the integration of apprenticeships within the diploma framework” (Tomlinson-Committee, 2004). It is therefore of vital importance not only to each individual apprentice, but also to their employers and families, that an uninterrupted progression route is made through the mandatory seven training phases. Hold-ups due to examination referrals can be a source of anguish for many apprentices and can sometimes be caused by learning and teaching practices as discussed in the preceding chapters. Through experience at management level it is evident to me that when one sees well-trained apprentices, it is normally associated with a very professional company with a high standard of management and training policies. It therefore makes commercial sense to produce high quality craftspeople that are dependable and add to the company profile.

There are also apprentices who have completed all off-the-job phases and did not receive a National Craft Certificate. Failure to reach the standard in the examination is the main reason why the certificate was not received (Conway, 2007). This in turn can lead to frustration and delays in achieving further awards within a lifelong learning context. Having parents and relatives come in to the college (post examination results) is a regular occurrence, often in an effort to see if additional revision or grind classes can be provided to students in the subject of mathematics. Repeating students have the added pressure of having to attend full time employment while also making time for study. This pressure can have an adverse effect on students' family lives and relationships and even on their health (Colley, James, Tedder, & Diment, 2003).

As the National Craft Certificate is not only recognised in the Republic of Ireland, but in other European Union and non-European Countries (Heraty, Morley, & McCarthy, 2000), many craftspeople also require this qualification for emigration or travel plans. This has never been as important as it is at present given the current economic downturn. To add to this "The European Union (EU) Lisbon Agreement of 2000 set in motion a process tending towards the harmonisation of vocational qualifications within the EU" (Clarke & Winch, 2006; Ertl, 2006).

Having identified within the literature, the many personal, local, national and indeed international problems associated with both third level and apprenticeship student's mathematical comprehension, and the subsequent effects of this, it seems obvious that learning and teaching techniques could be modified and/or improved in order to tackle this problem.

As can be seen throughout this literature review many authors have been critical of the traditional teaching and learning methods used for mathematics. Also the recommendation of adjusting teaching strategies whilst introducing techniques such as projects into the learning process has subsequently appeared many times. With such a broad body of academic literature in agreement on the 'mathematical problem' along with the need to introduce innovative learning, teaching and assessment, strategies and techniques to overcome it. It was thought appropriate to investigate the effectiveness that project-based learning might bring to Plumbing apprenticeship mathematical learning, teaching, assessment, enjoyment and understanding.

2.3 Project-Based Learning (PBL)

2.3.1 Defining Project-based Learning

Project-based learning is an entire pedagogical approach to learning and teaching with a long history. As far back as the 1900s, John Dewey (Grant, 2002) and William Heard Kilpatrick (Heitmann, 1996) supported ‘learning by doing’. It is designed to focus on teaching by engaging students in investigations of authentic problems (Blumenfeld, et al., 1991) and also includes curriculum design, tutoring, assessment practices, support and feedback (Barron, et al., 1998). This style of self-directed learning can also support and contribute to an engagement with lifelong learning (Fischer & Scharff, 1998). The use of both summative and formative methods of assessment and feedback are essential for a balanced account of a student’s performance (Markham, Larmer, & Ravitz, 2003). Project-based learning has been defined as problem and/or project-based learning (Stewart, 2007), where similarities are that both methods endeavour to mimic professional situations in either exploring a problem or a project with more than one way to either solve the problem or implement the project. However, the essence of project-based learning is that a question or problem serves to organise and drive activities; and these activities culminate in a final product that addresses the driving question (Blumenfeld, et al., 1991). The main idea beyond both project work and problem-based learning is the emphasis on learning rather than on teaching (Kolmos, 1996). For the aim of this research study the term PBL is taken to mean project-based learning, even though all project-based activities involve *inter alia* problem solving of one kind or another (Gibson, 2003).

PBL is a constructivist pedagogy that intends to develop deep learning by allowing learners to use an inquiry-based approach to engage with issues and questions that are real and relevant to the subject being studied (Milentijevic, Ciric, & Vojinovic, 2008). It also places students in realistic, contextualised problem solving environments where projects can build bridges between phenomena in the classroom and real-life experiences (Blumenfeld, et al., 1991). The nucleus of the student’s activity consists of building meanings related to their own previous experience (Moreno-Armella & Waldegg, 1993) and is designed to be used for complex issues that require students to explore in an effort to fully understand (Barron, et al., 1998). The projects will have varying complexity, but all will relate in some way to the fundamental theories and techniques of the discipline (Mills & Treagust, 2003).

Being learner centred, PBL provides learners with the opportunity for in-depth investigations of worthy topics (Grant, 2002), where the role of the teacher is to support, guide and facilitate this constructive process rather than to transmit discrete knowledge (Stipek, et al., 2001). "The teacher is no longer a content expert but, more importantly, an expert of learning and problem-solving processes" (Stauffacher, Walter, Lang, Wiek, & Scholz, 2006). Within engineering education over the past number of years there has been a paradigm shift with an emphasis that reflects away from traditional teaching styles, towards a more constructivist view of learning and assessment, (Gibson, 2003). "This shift has involved a greater use of projects in the learning and assessment process" (Gibson, 2003, p. 331).

PBL involves students having to participate in the learning and teaching process. Learning from one another invariably leads to teaching one another, the most vibrant form of knowledge acquisition. Lave and Wenger's work (as cited in Colley, et al., 2003) has been influenced in advancing this concept of learning not as acquisition, but as participation. They argue that it is social participation, rather than cognitive acquisition, which enables newcomers to learn from more experienced practitioners.

2.3.2 PBL Pedagogical Issues

The pedagogical rationale for introducing real-world mathematical projects to apprentices is to provide learning experiences that help to develop competency in practical problems (Baldock & Chanson, 2006). With traditional teaching methods, far too many students are motivated by situations that encourage the use of surface learning rather than deep learning approaches, i.e. memory recall rather than understanding (Gibson, O'Reilly, & Hughes, 2002). Project-based learning differs in so far as students are encouraged to generate questions (Helle, Tynjala, & Olkinuora, 2006; Mills & Treagust, 2003) and take responsibility for their own learning (Gibson, et al., 2002), (Oldfield & Rose, 2004). The projects are designed to be relevant, yet challenging enough to encourage students to generate these questions, which is in sharp contrast to the ‘chalk and talk’ pedagogy where education equals the answer to questions that no one ever asked (Helle, et al., 2006). Engaging students through dialogue and critical pedagogy is thus claimed to be an important focus for vocational educators (James & Mulcahy, 2000). These projects may be carried out by individuals or in small working groups (Mills & Treagust, 2003). There will always be a final result, (in the case of this study, a mathematical plumbing design) which partly rounds off the project work process from a cognitive point of view (Kolmos, 1996).

PBL is pedagogically based on constructivist learning in a setting represented by Kolb’s learning cycle (Appendix 10) (Lenschow, 1998). Kolb observed that the effective learner relies on four different learning modes: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), and Active Experimentation (AE). That is, he must be able to involve himself fully, openly, and without bias in new experiences (CE), he must be able to reflect on and observe these experiences from many perspectives (RO), he must be able to create concepts that integrate his observations into logically sound theories (AC), and he must be able to use these theories to make decisions and solve problems (AE), and the idea is that the cycle should be repeated (Kolb, 1984).

Project-based learning projects are also adaptable to different types of learners and learning situations (Blumenfeld, et al., 1991). “In terms of the main pedagogical concepts of experiential learning e.g. Kolb 1984, and collaborative learning e.g. Piaget 1963, Vygotsky 1978, the projects and their assessment encompass a mix of different aspects, i.e. the ‘make’ or ‘do’, the problem and the acquisition of new skills” (Baldock & Chanson, 2006). By placing the emphasis on the student’s activity, teaching methods based on constructivist theories also demand greater activity on the part of the teacher (Moreno-Armella & Waldegg, 1993). The activity required by this conception is less routine, often unpredictable, and also requires constant creativity on the part of the lecturer (Moreno-Armella & Waldegg, 1993). This project advising, with its ever changing real-world orientation, also takes more time than repeating well-developed lecture notes (Schachterle & Vinther, 1996).

Assessment within project-based learning must involve methods that focus on understanding rather than just memory recall and surface learning. The National

Council of Teachers of Mathematics, Standards, (NCTM, 2009) emphasise that mathematics need to be taught as a dynamic tool for thought, not just a set of operators to be learned. The standards also stipulate that students need opportunities to communicate mathematical ideas and solve problems with others, and that teacher's should use assessment strategies that focus on understanding rather than on correct answers (Stipek, et al., 2001).

> This approach to mathematics instruction referred to often as 'inquiry-orientated' (also 'constructivist' or 'social-constructivist'), represents fundamental changes in teaching practices – a shift away from the exclusive use of more traditional textbook-based teaching, in which the teacher is in complete control and the students' only goal is to learn operations to get the right answer (Stipek, et al., 2001).

It is in an effort to change the perception that mathematics is a challenge to just 'get the right answer'; to an understanding of the meaning of the project task, that has motivated this action research study. I believe that this pursuit can be helped to some extent with the introduction of PBL within apprenticeship education. These project tasks need also to be carefully constructed and relate to real world design problems as, previous work on tasks suggests that they serve as critical links among student motivation, student cognition, instruction and learning (Blumenfeld, et al., 1991). They also argue that through the introduction of more cognitively complex tasks, which provide opportunities for solving real problems, students may overcome their lack of understanding of content and process, along with poor attitudes towards learning.

2.3.3 Assessment within PBL

Many tools can be used for assessment within PBL, but all are pushing towards the common goal of creating a framework to assist learning and understanding. This scaffolding should support students in their assessment, self-assessment, and presentations whilst also facilitating reflective learning (Willey & Freeman, 2006). While developing appropriate assessment methods a number of key questions need to be addressed, these include:

- Does the assessment align with the learning outcome?
- Is the assessment fair?
- Is it of high academic standard?
- Does it cover the subject area comprehensively?
- Does it engage the students' interest?
- Is it designed in such a way that the student can complete it and that it can be marked in a reasonable time?

  (Carroll, 2005)

Based on the outcomes of their research study Bergh, et al, (2006) also emphasise that integrating learning, instruction and assessment within PBL is necessary and that one cannot go without another.

2.3.4 Constructive Alignment:

In order to introduce this constructivist type of learning to students, a great deal of effort and thought must be put into the curriculum. This must ensure that the learning outcomes, assessments, and the learning and teaching strategies are aligned (Pearson, Barlowe, & Price, 1999). This process known as 'constructive alignment', developed by Professor John Biggs is of vital importance if a student centred system of project-based learning is to succeed.

The main steps in constructive alignment are:

1. Defining the intended outcomes (the curriculum objectives)
2. Choosing teaching/learning activities likely to lead to help and encourage students to attain these objectives
3. Engaging students in these learning activities through the teaching process
4. Assessing students learning outcomes using methods that enable students to demonstrate the intended learning and evaluating how well they match what was intended
5. Arriving at a final grade, and perhaps in the case of formative assessment, giving feedback to help students improve their learning

   (Biggs, 2003)

The finer examples of project-based learning also offer an opportunity for closure, debriefing or reflection (Grant, 2002). With assessment playing such a key role in PBL, Willey and Freeman (2006), also point to such techniques as oral presentations, self and peer assessment, for individuals working within a group in an effort to discourage free-riding team members.

Within PBL there is also a route back for students to recover from mistakes and then carry on. In my experience this process is representative of real-life working practices in plumbing design. Here many designs will prove to be practically unachievable in the field and a complete redesign will be necessary. As there are no uniquely defined solutions for each project (Heitmann, 1996) there is also an opportunity here for the teacher to learn from innovative student submissions.

In their research paper on PBL assessment Bergh, et al, (2006) list the following assessment methods that they presented to students.

- Self-assessment, (self assessment refers to the involvement of learners in making judgements about their own learning process)

- Peer assessment, (an assessment method in which groups or individuals rate their peers)

- Co-assessment, (in co-assessment, or collaborative assessment, both the students and the staff participate in the assessment process)

- Performance assessment, (performance-based assessment requires students to actively accomplish complex and significant tasks, while bringing to bear prior knowledge, recent learning and relevant skills to solve realistic or authentic problems)

- Reflective Journal, (learning journals or reflective journals are used to document students' reflections on the learning process)
  (Bergh, et al., 2006)

While also listing validity and reliability as good characteristics of PBL assessment PBLE-Guide (2003) also advise of assessments having four purposes, namely,

- Formative, (giving feedback that helps the student to shape his or her future learning)

- Summative, (providing a judgement of performance, such as a grade)

- Diagnostic, (helping the lecturer identify which parts of the programme are causing difficulties)

- Informative, (providing the student with a clear understanding of the purpose of the module and how it integrates with other studies)
  (PBLE-Guide, 2003)

The PBLE-Guide (section 8.4) also generally concurs with Berg, et al, (2006) in their list of recommended assessment methods (Appendix 11)

2.3.5 PBL integration within apprenticeship education

Speaking of engineering education in general, Mills and Treagust (2003) postulate that the dominant pedagogy is still 'chalk and talk'; despite the large body of educational research that demonstrates its ineffectiveness. They are graduating with good knowledge of fundamental engineering science, but they don't know how to apply that in practice (Mills & Treagust, 2003). This has been discussed in detail previously within this chapter and with plumbing calculations being directly related to engineering the problems here are similar.

The form of PBL thought most suitable for integration within this research study is 'Project Component' which is one of three models described by Helle et al, (2006). This model is student centred and interdisciplinary in nature and often related to real-world issues. The objectives include problem-solving abilities with a capacity for independent work where traditionally taught courses are often studied in parallel with the project course (Helle, et al., 2006). This particular study is similar, where other lecturers using traditional teaching methods will cover most of the FÁS curriculum in parallel with this research project. This is also very similar to Heitmann, (1996) who differentiates between 'project-oriented studies' and 'project-organised curriculum'.

According to Heitmann, the most common features in project-oriented studies are small projects or assignments within a certain subject or course, focusing primarily on the application of previously acquired knowledge encouraging active learning. Projects may be carried out by individuals or in groups within this type of study (Heitmann, 1996). Alternatively project-organised curriculum use projects as the structuring principle and element for the entire curriculum. Heitmann further separates project-oriented and project-organised studies into four approaches,

1. The education-orientated, didactic approach
2. The science-oriented, critical approach
3. The practice/project-orientated, professional approach
4. The culture and society-oriented approach

The growing gap between theory and practice gave prominence to the practice/project-orientated, professional approach in engineering (Heitmann, 1996) where there was an increasing inability of the higher education system to satisfy the needs of industry and society.

Project work can take many forms. In order to maximise the opportunities afforded by learning through projects it is important to identify the type of project that is best suited to the topic or subject area (PBLE-Guide, 2003). For this small-scale study on a single subject (plumbing applied calculations) within a large curriculum (FÁS phase six plumbing curriculum; version 2.2) it was thought appropriate, through action research, to adopt the project-component model (Helle, et al., 2006) with a project-orientated professional approach (Heitmann, 1996). The complete methodology of this integration, the research process and the research structural framework are fully discussed in Chapter Three.

In PBL, the process of constructing a concrete artefact (mathematical plumbing design), also forces the student or student team to think through the steps of the construction process, complete tasks in a logical sequence, just like a mechanical or construction team (Helle, et al., 2006). As there is a sequential logical and reflective path to be followed in this process, and where an understanding must be achieved in order to progress through the design, the reason for rote learning is practically removed.

I believe that this is, more representative and worthwhile to apprentices to achieve an understanding of why and where they can use design calculations directly in their line of work. It would appear a logical extension of plumbing design education to implement PBL in this respect.

2.3.6 Can the integration of PBL be successful

As referenced in detail earlier there is much evidence throughout the literature of a call for change in the way that mathematics is taught both in both secondary and third level education in Ireland. Further away in Hong Kong, PBL has been designed as a key educational innovation in their education reform (Education-Commission, 2000). Within their report one of the key recommendations is that "excessive dictation exercises, mechanical drilling, tests and examinations should be eliminated to allow students more time to participate in useful learning activities" (Education-Commission, 2000, p. 10). Also many universities around the world who are offering engineering programmes are engaging with PBL as a preferred form of learning (Stewart, 2007). "Outstanding examples include Aalborg, Drexel, Windsor and Surrey" (Stewart, 2007, p. 455).

Increasingly, engineering educators, employers, professional accreditation organisations and universities have recognised that PBL shapes a pedagogical environment with desirable characteristics (Schachterle & Vinther, 1996). A study carried out in the USA shows that PBL has proven to be a successful and popular development whilst also providing enhanced understanding and enthusiasm, when it was introduced on a course for numerical methods (Musto, 2001). This call for change from lecture-centric programmes is also coming from students, professional institutions and industry (Mills & Treagust, 2003). The European Society for Engineering Education in their mission statement also recognise that the teaching and learning environment in Europe is moving from "classical" lecturing to project oriented education and e-learning, etc (SEFI, 2005).

In the United Kingdom with financial support from the Fund for the Development of Teaching and Learning (FDTL) (HEA, 2009), four universities joined together, namely, Nottingham, Loughborough, Nottingham Trent and DeMonfort to form; Project Based Learning in Engineering (PBLE-Guide, 2003), with an aim to enhance engineering education by promoting and facilitating the use of learning through projects, thereby improving students' key transferable skills and their grasp of the subject content, they state that,

> Within engineering, project based learning is likely to be an effective means of teaching and assessing a range of relevant skills and qualities. The engineering benchmark statement specifically identifies extended project work as an important tool for the development of many of the skills needed by the graduate engineer (PBLE-Guide, 2003).

Rooted in constructivism and with strong theoretical support for successful achievement, PBL offers an engaging method of instruction to make learners active constructors of knowledge (Grant, 2002). Learning environments rooted in this constructivist paradigm therefore regard student learning as the core issue and define teaching as enhancing the learning process (Bergh, et al., 2006). Project-based learning is a well-known example of a powerful learning environment within this constructivist paradigm (Blumenfeld, et al., 1991), and gives learners the opportunity to develop more learner skills than traditional lecture based teaching (PBLE-Guide, 2003). Maybe then, instead of asking how we can teach better, should we be asking how we ensure that people learn better (Mills & Treagust, 2003), as knowing how to learn is a highly desirable skill for life (Oldfield & Rose, 2004).

The above literature indicates that PBL can be a successful learning and teaching method in providing students with a deeper understanding and interest in their chosen topics. It is in an effort to successfully integrate PBL into the applied mathematical module of plumbing apprentices' curriculum that forms the basis of this research study. This integration is being applied through the project-component model with a project-orientated professional approach. Using action research as the methodology for this approach, over three eleven-week phases or cycles was thought most appropriate. This is because the integration of PBL requires a change of teaching style with interaction and involvement required between student and facilitator with interventions being incorporated where applicable.

2.3.7 PBL and Action research

The aim of this action research study is two-fold which will incorporate both practical and theoretical elements. On a practical level I want to improve my learning and teaching practice, and on a theoretical level I want to investigate the processes involved in learning and teaching in this domain. “Research will have an impact on the practice of teaching if and only it produces, or leads to the production of, appropriate ‘techniques’ which can be adopted in the classroom” (English, et al., 1992, p. 761). The development of learning and teaching project-based techniques can I believe be appropriately applied to apprenticeship mathematical programmes. Others who are involved in similar practices may also find this research framework useful, which may generate improvement in practice and the production of theory and knowledge.

It was not be my intention to develop an end product but produce a work in progress that would stay alive and evolve over time with further reflection and analysis. The reason for my choice of investigation was that action research can bridge the gap between research and practice (Somekh, 1995), (A means of forging links between practical and theoretical concerns). The aim of doing action research as a teacher, is to achieve educationally worthwhile changes, whilst at the heart of this are considerations of curriculum and pedagogy (McKernan, 1996). Broadly speaking, educational action research can be described as qualitative, practical, participatory, reflective and concerned with social change, which offers a means of providing an understanding to a problematic situation (Opie, 2004). The rationale for adopting this approach was that it “directly addresses the persistent failure of research in the social sciences to make a difference in terms of bringing about actual improvements in practice” (Somekh, 1995). Many social scientists write up research in a language and with concepts that are incomprehensible to the people who are the ‘subjects’ of the research and also those outside the university who may wish to use the findings (Greenwood & Levin, 2005). As an alternative approach Greenwood and Levin

(2005) suggest that action research is key to the fundamental transformation of the behaviours needed by those engaged in social science.

One of the early thinkers on action research was Kurt Lewin, who described action research as a cyclical process of diagnosing a change situation or a problem, planning, gathering data, taking action, and then fact-finding about the results of that action in order to plan and take further action (Rowley, 2003). This fits in well with the design of this research project (further discussed in Chapter Three) and within the apprenticeship programme on which I lecture. This study was conducted using action research with three groups of ‘phase six’ plumbing apprentices. Each group comprised of sixteen students per term making a total of 48 students over three terms, which suited the cyclical nature of this type of methodology. This particular analysis was carried out over three eleven week apprenticeship terms from September 2009 to June 2010. Describing action research to a greater extent, the Action Research Resources state that,

> Action research can be described as a family of research methodologies that pursue action (or change) and research (or understanding) at the same time. In most of its forms it does this by using a cyclic or spiral process that alternates between action and critical reflection and in the later cycles, continuously refining methods, data and interpretation in the light of the understanding developed in the earlier cycles. It is thus an emergent process that takes shape as understanding increases; it is an iterative process that converges towards a better understanding of what happens. In most of its forms it is also participative (among other reasons, change is usually easier to achieve when those affected by the change are involved) and qualitative.
> ("Action Research Resources," 2009)

Action research is a cyclical or spiral research process with a proactive orientation. At the teaching/learning nexus, it involves mathematics teachers studying their own teaching, identifying an interesting aspect, collecting evidence about it and then acting on the results (English, et al., 1992). They further argue that educational administrators and ministries of education must ensure that such research findings become incorporated into 'tangibles' such as syllabi, methods, materials, etc., which can be adopted by the practitioner at classroom level. In this connection, English, et al., (1992) argue positively for the adoption of 'action research' techniques in the routine practice of mathematical teaching. It is in light of the above and the fact that I am actively involved within this change to a PBL technique, that action research methodology was thought most appropriate for this study. A more in-depth analysis of action research with a range of epistemological and methodological issues related to its practice is further discussed in Chapter Three.

2.4 Chapter Summary

The research question presented at the start of this chapter necessitated this literature review to be sectioned into three areas. Firstly an investigation of the literature regarding experiential and observational findings on the difficulties that student apprentice's are experiencing with mathematics was carried out. Concurrent to this it was thought appropriate to search the literature in an effort to establish if this lack of basic mathematical comprehension and knowledge was reflected throughout tertiary education in general. From here it was considered essential to further investigate in an effort to gain an understanding of why mathematics seem to be problematic for many third level students and apprentices who have been exposed to mathematics education from second level. One of the most striking outcomes of this section of the review was the volume of literature citing criticism of the teaching and learning methods used within second level mathematical education. From the literature review a major issue that has emerged is the wide gap that is apparent between the ideal and real practices in mathematics classrooms. "The relevant literature also highlights that the pressure on schools to deliver good examination results seriously weakens the greater aim of providing a high quality mathematics education" (Hourigan & O'Donoghue, 2007, p. 465).

Apprenticeship education was then reviewed in detail where the importance of both on and off-the-job training was discussed from both a general and mathematical viewpoint. While an comprehensive search of the literature in relation to Irish apprentice education has proved limited (Goggin, 2004), there are many references to international apprenticeships educational systems. The literature in this respect suggests that while there are many advantages of on-the-job training (particularly for practical subjects), a blended approach where apprentices are afforded time to study off-the-job, seems to satisfy a more comprehensive learning environment for all concerned.

This literature review was also framed by a discussion of the context and motivation for the study, which is the introduction of project based learning within the mathematical education of plumbing apprentices in an effort to improve their understanding. The literature exploration in this respect exposed a large amount of supporting evidence on the possible benefits of introducing PBL within second and third level education.

As this small scale research project is being carried out and reviewed over three apprenticeship terms and with a change of learning and teaching technique to PBL, the cyclical and interactive nature of action research was also reviewed and adopted. Action research is further reviewed in Chapter Three.

Since applied calculations is so fundamentally important to apprentices, I believe it is necessary to change their perceptions of the subject from one of endurance to one that can be actively used and enjoyed.

Chapter Three

Research Design

3.1 Introduction

Typically, research starts off with a real-life concern that needs to be addressed, a problem that needs to be solved or a question that needs to be answered (Crotty, 1998). As this project is based on educational research, this can be described as the "collection and analysis of information on the world of education so as to understand and explain it better" (Opie, 2004, p. 3). It is about creating new knowledge, testing its validity and sharing this knowledge for specific purposes (McNiff, et al., 2003). One of the tasks of the researcher is to investigate and find things out, to analyse and interpret the findings and to make sense of the research study as a whole (Sikes, 2004). In the design of any research, a study of the different approaches and procedures will give an insight into the different ways of planning an investigation while also enhancing an understanding of the literature (Bell, 2005). These approaches come from very different knowledge traditions with different theories and principles underpinning them (Grbich, 2007). These approaches and procedures are predominately in the form of either quantitative or qualitative research, which are further discussed in the following sections of this chapter.

Different well-established methodologies, traditions or approaches to research use different data collection methods, but no approach stipulates nor automatically rejects any particular method (Bell, 2005). It is also possible that either quantitative or qualitative methods can be used separately or both together to serve the research purpose without this being problematic (Crotty, 1998). However, an understanding of the main advantages and disadvantages of each approach is likely to help in the selection of an appropriate methodology that best suits the research question or task (Dick, 2002; Love, 2000; McNiff, et al., 2003). The approach and procedure *or* research methods adopted will normally depend on the type of information required, the nature of the enquiry and the context of the research (Opie, 2004). This chapter presents an outline of the most well established research methodologies and also gives a rationale of this researchers positionality and why action research has been chosen as the methodology for this particular study.

3.2 Qualitative / Quantitative Debate

Since the Ancient Greeks, there has been disagreement between philosophers about how we should obtain our knowledge (Knight & Turnbull, 2008). As discussed above, research can be quantitative or qualitative or mixed. However, it would be problematic to declare oneself both objectivist and constructionist (or subjectivist) (Crotty, 1998). Guba and Lincoln (2005) also argue that at the paradigmatic, or philosophical level, compatibility between positivist and postpositivist worldviews is not possible, but mixed methods within each paradigm make perfectly good sense. Researchers therefore, need to be epistemologically and paradigmatically consistent in order to be aware of how their positioning and the fundamental assumptions they hold might influence their research related thinking and practice (Sikes, 2004).

The historic Parsons – Schutz debate in the 1940's has highlighted some of the main differences in the social sciences (Hart, 2005). It is important to note that this is not a quantitative-qualitative argument, as is a commonly mistaken assumption, but it is an objective-subjective or positivist-interpretivist dispute (Hart, 2005). Krauss (2005) also agrees that ultimately the heart of the quantitative - qualitative debate is philosophical, not methodological. One of the biggest issues surrounding the debate is that of validity and in particular between method and interpretation (Guba & Lincoln, 2005). However, Allison & Pomeroy (2000) also argue that qualitative researchers are still more likely to struggle for legitimacy than quantitative researchers.

In recent years though, the number of qualitative texts, research papers, workshops and training has exploded (Guba & Lincoln, 2005). Nowadays there can be no doubt that the legitimacy of postmodern paradigms is well established and at least equal to the legitimacy of conventional paradigms (Guba & Lincoln, 2005). These criticisms and debates have led to seemingly endless polemics that are often referred to as paradigm wars (Miles & Huberman, 1994). However Guba and Lincoln (2005) argue that these various paradigms are beginning to 'interbreed' where previously two conflicting theorists may now appear, under a different theoretical rubric, to be informing one another's arguments.

In conclusion on the paradigm debate Guba and Lincoln (2005) argue that at the postmodern moment it is unlikely that there will be a 'conventional' paradigm to which all social scientists will subscribe to in some common terms and with a mutual understanding.

3.3 Researcher Positionality

One of the most significant factors that affects the choice and use of methodologies and methods is the philosophical position of the researchers and their fundamental assumptions concerning, social reality (their ontological assumptions) and the nature of knowledge (their epistemological assumptions) (Avramidis & Smith, 1999; Sikes, 2004). These philosophical assumptions about the nature of reality are vital to understanding the overall perspective from which a research study or project is designed and carried out (Krauss, 2005). There are many topics within social sciences that are deeply embedded with personal meaning (Krauss, 2005) and as such, researchers approach their studies with a basic set of beliefs or assumptions (sometimes unknown to them) that guide their enquiries (Creswell, 1998). Assumptions of this nature are influenced by values and beliefs born from, for instance, political allegiance, religious faith, social class, ethnicity, gender, sexuality, historical and geographical location, and so forth (Sikes, 2004). Educational researchers' assumptions about ontology and epistemology are therefore, intimately bound up with, and impact upon, their decisions about methodology and methods (Grix, 2002). Researchers undertaking small-scale projects similar to this one, need to balance the practicalities of doing the research with the philosophies that underpin their engagement with it (Morrison, 2002).

Many student and academic researchers have difficulty in differentiating between crucial terms such as ontology (that is, what is out there to know about) and epistemology (that is, what and how can we know about it), (Grix, 2002). It is worthwhile therefore, to discuss and show the interrelationship between some core concepts of social science (ontology, epistemology, theoretical perspective, methodology and methods). It is also important to a reader of an academic research study, to know the ontological and epistemological position of the author, as different approaches will have a significant impact on the type of results that are gleaned from the research (Allison & Pomeroy, 2000). The argument for epistemological awareness and methodological transparency is especially important in the current political and academic climate, where many question the design choices and validity of qualitative research studies (Koro-Ljungberg, Yendol-Hoppey, Smith, & Hayes, 2009). The philosophical position or commitment of educational researchers also affects what they investigate as well as how they go about the task (AERA, 2009).

3.4 Ontology and Epistemology

Over thousands of years, various theories have been developed by philosophers to answer the difficult questions surrounding the status of knowledge (Knight & Turnbull, 2008). However, the philosophical terminology used in both research design literature and social sciences texts is far from consistent where sometimes the same term is used in different or even contradictory ways (Crotty, 1998). Likewise, the methodological literature of the social sciences is full of complex and advanced level arguments (Hart, 2005). In an effort not to get bogged down in irresolvable philosophical argument (Knight & Turnbull, 2008), this chapter will attempt to define how these terms have been interpreted for use in this project.

Ontology is concerned with the nature or essence of things (Sikes, 2004) and is the starting point of all research, from which one’s epistemological and methodological positions logically follow (Grix, 2002). Ontology is the study of being, and influences the way in which we view ourselves in our relationships with others (McNiff & Whitehead, 2006). A similar definition of ontology is also given by Love (2000) as being the philosophical study of reality and being. He further describes ontology as the exploration of the fundamental kinds of things that exist in the world (Love, 2000). Although the views that a person has on research will be dependent on a number of factors, their epistemology will also be one of the most significant aspects (Opie, 2004). Opie defines this as meaning a persons view of how knowledge is acquired and how it can be communicated to others. Crotty (1998) also describes epistemology as a way of understanding and explaining how we know what we know.

Epistemology also refers to the question of how we know the world and is the technical term for the ‘theory of knowledge’ (Christou, Valachis, & Anastasiadou, 2009). In simpler terms, epistemology looks at the relationship between the investigator and what can be known by direct observation of the external world to uncover knowledge (objectivists), or when the observer and the subject of the investigation must interact to create knowledge (subjectivists) (Christou, et al., 2009).

As writers in the research literature have difficulty in keeping them apart, Crotty (1998) asserts that ontology sits alongside epistemology on the research framework, where each would inform the theoretical perspectives (research paradigms) of the researcher. “For each theoretical perspective embodies a certain way of understanding *what is* (ontology) as well as a certain way of understanding *what it means to know* (epistemology)” (Crotty, 1998, p. 10). Also discussing philosophical assumptions, Sikes (2004) firstly separates ontology from epistemology. Although, in terms of research design and choice of procedures, there are objective and subjective assumptions and these differences are much the same as those identified with regard to both ontological and epistemological assumptions (Sikes, 2004). As can be seen, epistemology is intimately related to ontology (Krauss, 2005) and it becomes difficult to consider one without the other (Allison & Pomeroy, 2000). Love (2000) also reinforces the view that this meta-epistemological interrelationship presents few problems with it being more important the ways in which the roles of ontology and epistemology change between positivist and post-positivist research situations. Positivists express assumptions that are consistent with quantitative research philosophy, while post-positivists reject positivism, expressing a more qualitative philosophical position (Onwuegbuzie, 2000). Guba and Lincoln (2005), also assert that new-paradigm researchers (critical theorists, constructivists) have seen the preeminent paradigm issues of ontology and epistemology effectively folded into one another. Postmodernists also show that once attention is paid to the history of knowledge, it is hard to separate knowledge from our surrounding environment and thus from ontology (Knight & Turnbull, 2008).

Researchers therefore, need to be aware of and understand that different views of the world and different ways of gathering knowledge exist (Grix, 2002). There is also a tendency in some of the literature for authors to use the words perspective, paradigm and approach as having equivalent meanings (Morrison, 2002). Often there is little paradigmatic purity with different labels being used in various texts (Avramidis & Smith, 1999). With this insufficiently precise use of terminology in the literature (Green, Azevedo, & Torney-Purta, 2008) and for sound research intelligibility it was thought appropriate to use Crotty's (1998) theoretical research framework or *scaffolding* as a guide in this project. Others within the literature have also built on Crotty's theoretical perspective (Koro-Ljungberg, et al., 2009) for guiding their research project. For reasons of presentational clarity this is shown in diagrammatical form below.

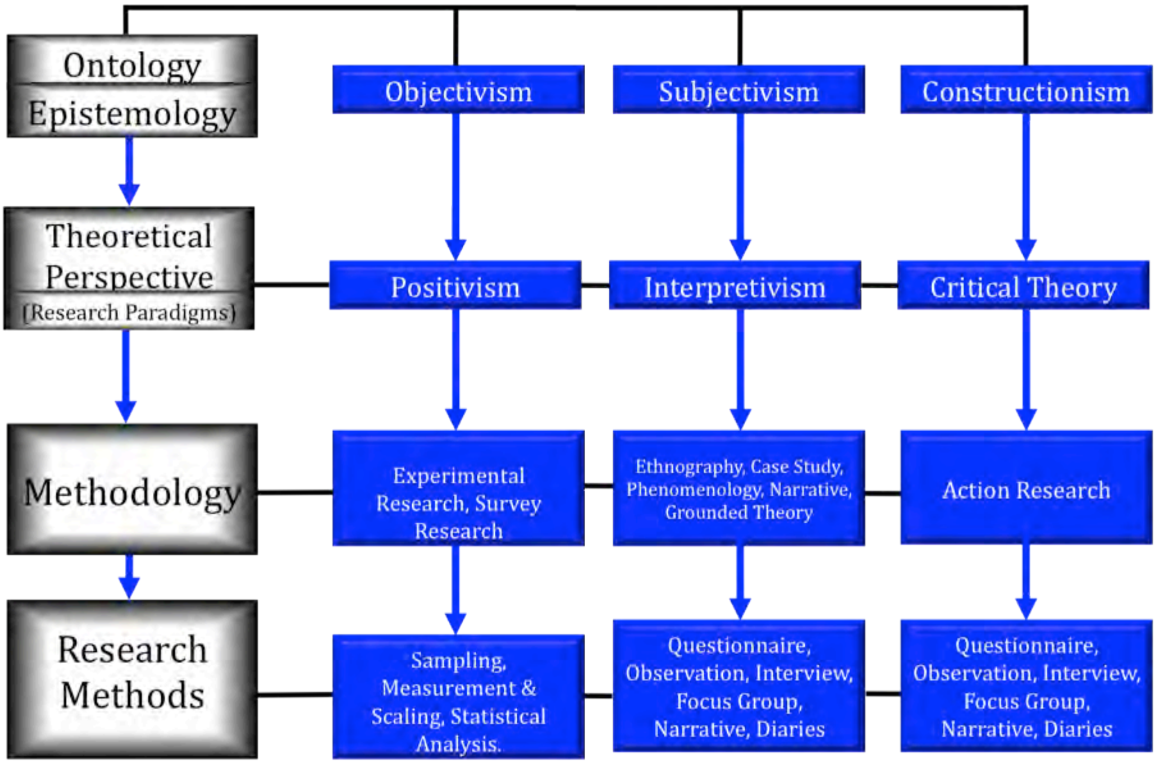


Chart Adapted from Crotty (1998)

The epistemological assumptions shown in the above diagram fall into the following three main underpinning categories;

- Objectivism
- Constructionism
- Subjectivism

It is how, in these terms, that researchers view the social world as having implications for the sorts of theoretical perspectives, methodologies and methods they are likely to consider to be ‘valid’ means of collection and interpretation of data in an effort to create ‘valid’ knowledge (Sikes, 2004). “These beliefs shape how the qualitative researcher sees the world and acts on it” (Denzin & Lincoln, 2005, p. 22). Epistemological considerations guide and underpin all aspects of the research process including the foundations for the data analysis process (Krauss, 2005).

Objectivist epistemology holds the view that meaning, and therefore meaningful reality, exists independently from the operation of any consciousness (Crotty, 1998). From a purely objective standpoint, knowledge has to be built upon demonstrable facts and observations (Opie, 2004). This is the epistemology underpinning the positivist stance where the social world is seen as given and independent, where it can be observed and accounted for through ‘objective’ and quantifiable data using survey research, statistical analysis (Sikes, 2004) and experimental approaches (Williams, 2006).

Constructionist epistemology rejects the above view of human knowledge in that there is no objective truth waiting to be discovered, instead truth or meaning, comes into existence in and out of our engagement with the realities in our world (Crotty, 1998). “Meaning is not discovered, but constructed” (Crotty, 1998, p. 9). In general, qualitative research is based on a relativistic, constructionist ontology/epistemology that puts forward that there is no objective reality (Krauss, 2005). Data is collected by means of subjective accounts and perceptions that explain how the world is experienced and constructed by the individuals who live in it (Sikes, 2004). In educational research, constructionism emphasises the activity of the learner in constructing knowledge (Hepburn, 2006). This is the epistemology that may underpin the critical theory stance where research might be carried out using qualitative or quantitative research methods. It is towards this constructionist epistemological assumption that I would position myself within the context of research design and thought. Allison & Pomeroy (2000) also draw our attention to the fact that an incongruent epistemology is often employed in research in this field, where an outcome-focused objectivist epistemology tends not to compliment the subjective nature of human experiences.

Subjectivist epistemology takes the anti-positivist stance that knowledge is regarded as belonging to the individual as a result of their own consciousness and thoughts (Opie, 2004). It has been defined as being the "inner state of the self constituted by thinking, experience, emotion, belief, intentionality, self-awareness and the awareness of others (Boyne, 2006). Prominence is given here to individual points of view and where collective opinion is of secondary importance (Opie, 2004). Crotty, (1998) feels that this is the notion that people often describe when they claim to be talking about constructionism. Subjectivism is the epistemology underpinning the interpretative stance where research is usually carried out with a qualitative methodology using research methods that focus on individuals or small groups and being more concerned with understanding personal constructs (Opie, 2004).

From the above diagram it can be also be seen that ontological and epistemological assumptions give rise to theoretical perspectives which in turn give rise to methodological considerations and these, in turn, give rise to research methods and data collection. This approach moves beyond regarding research methods as simply a technical exercise. "It identifies that research is concerned with understanding the world and that this is informed by how we view our world(s), what we take understanding to be, and what we see as the purposes of understanding" (Cohen, Manion, & Morrison, 2000, p. 3).

3.5 Theoretical Perspective (Paradigms of Research)

Educational research has absorbed three main and competing views of the social sciences (Cohen, et al., 2000) – the established traditional positivist view, the interpretive view and critical theory. These three views are very different ways of looking at social reality and the research constructed from either perspective will have diverse means of interpreting it. While research methods can be used interchangeably it is difficult to mix research paradigms within the same research project without damaging the integrity and validity of the study (Stringer, 2008).

Investigators adopting the traditional objectivist (or positivist) approach to the social world and who treat it like the world of natural phenomena as being hard, real and external to the individual will choose predominately from a range of traditional quantitative methods – surveys, statistics, experiments, and other similar methods of the natural sciences (Carr & Kemmis, 1986; Cohen, et al., 2000). Positivists claim that commonsense, everyday knowledge and understanding is flawed as it is not systematic, sceptical and free from values, and is therefore not objective (Hart, 2005; Wellington, 2000). Scientific positivism therefore, assumes that ultimately, in principle, everything in the universe can be accurately measured and the relationship between things can be described with precision (Stringer, 2008). Human considerations are also excluded, and the focus is on the objectively observable properties of objects, and their behaviour (Love, 2000).

Researchers favouring the more subjective (or anti-positivist/interpretative) approach will view the social world as being a much softer, personal and humanly created kind, will select from a range of mainly qualitative methods – observation, interviews, open ended questionnaires, and the like (Cohen, et al., 2000). Interpretative approaches focus on the conscious and unconscious aspects of human cognition that form the development of human knowledge (Love, 2000). These approaches seek to replace the scientific notions of positivists, with interpretative notions of understanding, meaning and action (Carr & Kemmis, 1986).

Educational researchers favouring the constructionist (or critical theory) approach regard the two previous perspectives (or paradigms) as presenting incomplete accounts of social behaviour by their neglect of the political and ideological contexts of much educational research (Cohen, et al., 2000). Its purpose is not merely to understand situations and phenomena but to change them also. "Critical theory is concerned with the purpose of the research and its impact upon society" (Allison & Pomeroy, 2000, p. 93) thus critical theorists have always advocated varying degrees of social action (Guba & Lincoln, 2005). My own personal approach to educational research is most influenced through constructionism and critical theory; Guba and Lincoln (2005) who also favour this approach describe their own and my feelings well with the following;

> We believe that the criteria for judging either 'reality' or validity are derived from community consensus regarding what is 'real', what is useful, and what has meaning (especially meaning for action and further steps). We believe that a goodly portion of social phenomena consists of the meaning-making activities of groups and individuals around those phenomena (Guba & Lincoln, 2005, p. 197).

As these meaning-making activities shape the action (or inaction) to be taken, they are of central interest to social constructionists/constructivists and critical theorists (Guba & Lincoln, 2005). As this is the epistemological/paradigmatic route that shapes this research study, these are further explored in the following paragraphs.

3.6 Constructionism

From a constructionists perspective, meaning is not discovered but is constructed (Crotty, 1998). As already mentioned, in educational research constructionism is defined as a theory that emphasises the activity of the learner in constructing knowledge (Hepburn, 2006) and is the epistemological stance that qualitative researchers tend most often to invoke (Crotty, 1998). Constructionism is also the ontological/epistemological vision that is claimed to be most prevalent in experiential educational practice, if not in the research in this field (Allison & Pomeroy, 2000). A constructionist view is that knowledge is established through the meanings attached to the phenomena studied and the researcher interacts with the subjects (unlike positivists) of the study to obtain data. The inquiry tends to change both researcher and subject. It is a view that all knowledge is constructed with interaction between human beings and their world, and developed and transmitted within an essentially social context (Crotty, 1998). Constructionism therefore, focuses on the meaning that individuals and groups make of the world around them (Allison & Pomeroy, 2000).

Different constructionisms have gained a substantial presence in social science and psychology over the years; *constructivism*, *social constructivism* and *social constructionism* (Hepburn, 2006; Young & Collin, 2004). These have been fostered by practitioners seeking approaches that are closer to everyday situations of practice than those available to them through theory and research (Young & Collin, 2004).

A distinction between constructivism and constructionism can be explained by the following.

> The former focuses on meaning making and the constructing of the social and psychological worlds through individual, cognitive processes while the latter emphasises that the social and psychological worlds are made real (constructed) through social processes and interaction (Young & Collin, 2004).

Whilst these perspectives differ they also share a common heritage. From a vocational training and educational perspective, where I believe the focus needs to be on both the individual and the social orientation, I would assume a more integrated position where I would share the epistemological assumptions of Guba and Lincoln (2005) as being social constructivist/constructionist. This fits well within apprenticeship education where there is both an individual and social aspect to their learning in the on and off-the-job periods of their training. Integrating both views can also enrich our understanding of how people learn and grow and illuminates the processes by which individuals come to make sense of their experience (Ackerman, 2010). One or other form of constructionism is the epistemology found in most perspectives (i.e. critical theory) other than those representing positivist and post-positivist paradigms (Crotty, 1998). It can also be seen from the above diagram (page 67), that epistemologies and theoretical perspectives need to be linked to one another rather than just sat side-by-side as comparable (Crotty, 1998). In recent times critical theory has appeared as the natural direction to take with action research methodology, given the emphasis on personal understanding (McKernan, 1996).

Social constructionism/constructivism and critical theory, which best describes the epistemological/theoretical perspective and positionality of this study is further linked to action research methodology and in particular that of critical participatory action research. This forms the theoretical and methodological framework of this study. In describing this link further, Guba and Lincoln (2005) refer to constructivist inquiry as resembling critical theory and participatory action research, with each creating the capacity in research participants for positive social change and improvement. The ‘subjects’ of critical participatory action research undertake their research as a social practice where research is directed towards studying, reframing, and reconstructing social practices (Kemmis & McTaggart, 2005). Critical participatory action research is further expounded below.

Mathematical education is not just the work that a teacher carries out in the classroom, but also other factors that intervene to make the learning and teaching of mathematics possible. These are, for example, the design and development of the curriculum, teaching methodologies and the construction of theoretical frameworks for educational research (Moreno-Armella & Waldegg, 1993). Teachers who bring life to these factors do so from the standpoint of their personal philosophical and epistemological convictions with respect to mathematics. Moreno-Armella & Waldegg (1993) further argue that although mathematical activity has been extremely fruitful over the past century, the same cannot be said for mathematical educational practice derived from a formalist conception, where results have been unsatisfactory.

In an effort to revise these conceptions Moreno-Armella & Waldegg (1993) ask the question, "'what is knowledge' – 'that thing' which has not been easy to transmit, perhaps because it is not something that can be transmitted since the teacher does not have it 'in a form' for consumption by the students – the latter must construct it, this is the thesis of the constructivist epistemology" (Moreno-Armella & Waldegg, 1993, p. 656).

The unsuccessful model of traditional or formalised teaching methodologies mentioned above and also fully discussed in Chapter Two gave rise to the introduction of mathematical project-based learning used within this research project. Student-centred PBL which is also fully discussed in Chapter Two, is embedded in constructivism giving learners an opportunity to construct their own meaning (Grant, 2002) where there is no 'object of teaching', there is an 'object of learning' (Moreno-Armella & Waldegg, 1993).

Using PBL as learning and teaching method of applied calculations and mathematics to student apprentices plays a central role in the whole theoretical research framework of this project. It can be seen that there is a necessary and rational bond between a constructionist epistemology, a critical theory theoretical perspective, an action research methodology, appropriate mixed research methods and a project-based learning and teaching approach. The educational researcher must find ways in which to represent not only the conclusions of the investigation but also the path of thinking and inquiry that has led to these conclusions (Sumara & Carson, 1997). Therefore, the organisational and theoretical research path of this project is shown diagrammatically below.

Theoretical Research Path of this Project

3.7 Critical Theory

Inquiry that aspires to the name ‘critical’ must be connected to an attempt to confront the injustice with action (Guba & Lincoln, 2005) in the struggle for a better world (Kincheloe & McLaren, 2005). Therefore, “critical research can be best understood in the context of empowerment of individuals” (Kincheloe & McLaren, 2005, p. 305).

With its intention to be transformative, the purpose of critical educational research is intensely practical – to bring about a more just egalitarian society (Cohen, et al., 2000) and to initiate action in the cause of social justice (Crotty, 1998). Also the significance of critical theory is immense as it suggests that a lot of social research is weak in comparison, as they accept and try to understand given agendas for research rather than bringing them into question (Cohen, et al., 2000). Carr and Kemmis (1986) argue further that positivist and interpretative approaches to educational research are inadequately justified and that a critical social science approach should be adopted.

Critical theorists believe that all research is value-based and not value-free (Avramidis & Smith, 1999), where the purpose is not simply to represent the world but to change it (Cohen, et al., 2000). These changes or reforms when in the context of educational practice are participatory and collaborative, conducted by those involved in education themselves (Carr & Kemmis, 1986). Critical research in general is usually applied to any research that challenges conventional knowledge bases and methodologies (Crotty, 1998) that make claims of scientific objectivity (Muncie, 2006). It does not take institutions and social and power relations for granted but calls them into question (Morrison, 2002). In an explanation of what constitutes as educational research, Bassey (1999) describes it as:

> Critical enquiry aimed at informing educational judgements and decisions in order to improve educational action. This is the kind of value-laden research that should have immediate relevance to teachers and policy makers, and is itself educational because of its stated intention to ‘inform’. It is the kind of research in education that is carried out by educationists, Bassey (as cited in Morrison, 2002, p. 8).

Part of the agenda of critical theory and critical educational research is the social construction of knowledge and curricula, which also links this perspective with the above discussion regarding constructionism. Not only does critical theory have its own research agenda, but it also has its own research methodologies, and in particular, action research (Cohen, et al., 2000). Indeed, Weiskopf and Laske (1996) locate action research squarely as a ‘critical social science’ (as cited in Cohen, et al., 2000). Within this methodology some research methods are privileged over others (Creswell, 1998) (these research methods are fully discussed in Chapter Four).

Critical theory invites researchers and participants (ideally one and the same) to open themselves to new ways of understanding, and take effective action for change (Crotty, 1998). This very much describes this action research project where student apprentices were asked to participate with the researcher to change to an alternative mathematical learning and teaching method in an effort to seek improvement of understanding. One of the main aims of action research is personal growth or as some describe it ‘empowerment of the individual’ and it is rooted in the ideas of critical theory perspectives (Somekh, 1995).

As discussed in Chapter Two, it is not the intention of this research project to develop an end product but instead to produce a work in progress that may stay alive and evolve over time with further reflection and analysis. In the same way, critical theory or critical enquiry cannot be seen as a piece of work that achieves its objectives and comes to a close (Crotty, 1998). Critical enquiry is therefore never static (Kincheloe & McLaren, 2005) but emerges as an ongoing project seen as a reflective spiralling process of reflection and action (Crotty, 1998). This process also best describes and links to, the fundamental theory behind the action research methodology (Opie, 2004) used for this research study.

This whole research project/question revolves around the change from traditional didactic teaching methods to the introduction of the more student-centred, teaching and learning paradigm, of project-based learning. Within the research framework discussed above and from an underpinning constructionist/constructivist epistemology, a critical theory theoretical perspective has led to an action research methodology being used throughout this study. However, the methodology used for

this research study was chosen predominately to suit what the project is about, (the research question) and not because of a commitment to a particular paradigm. Grix (2002), also argues that we should guard against ‘method-led’ research rather than ‘question-led’ research, whereby questions point to the most appropriate research method (Avramidis & Smith, 1999; Crotty, 1998; Grix, 2002).
Although action research has been discussed to some extent in section 2.3.7 of Chapter Two, the particular style and form of action research used for this study is further discussed below.

3.8 Methodology – Action Research

Both ontological and epistemological assumptions adopted by any researcher will have a direct impact on their methodological choices (Christou, et al., 2009). In other words if we accept the philosophical assumptions discussed above, we are invariably drawn to the utilisation of methodologies best suited to that paradigm. These methodologies are concerned with the logic of scientific enquiry and in particular with the potentialities and limitations of different techniques (Grix, 2002). Methodology also refers to the theory of getting knowledge, to the consideration of the best methods, by which data will provide the evidence basis for the construction of knowledge about the topic being researched (Sikes, 2004). Researchers need to be sure that their methodologies and methods are aligned with their ontological/ epistemological position, as they need to make a convincing case for their practice in light of their assumptions (Sikes, 2004). The follow on from the research design in this project was the introduction of PBL.

As discussed in detail in Chapter Two the learning outcomes, assessments and learning & teaching strategies within this pedagogical paradigm need to be constructively aligned. The alignment of the research design framework in this study, followed by the constructive alignment of the learning, teaching and assessment methods, was carried out in an effort to maximise the rigidity of the investigation and encapsulate it into one complete structure. Elliott (1991) also recognises this as a unified conception of a reflective educational practice, which integrates teaching and teacher development, curriculum development and evaluation with research and philosophical reflection. For reasons outlined and discussed in the preceding sections of this chapter the methodology chosen for this project is action research. However, as there are various forms of action research (Somekh, 1995), it is worth discussing this methodology in more detail and present a rationale for the type chosen for this research project.

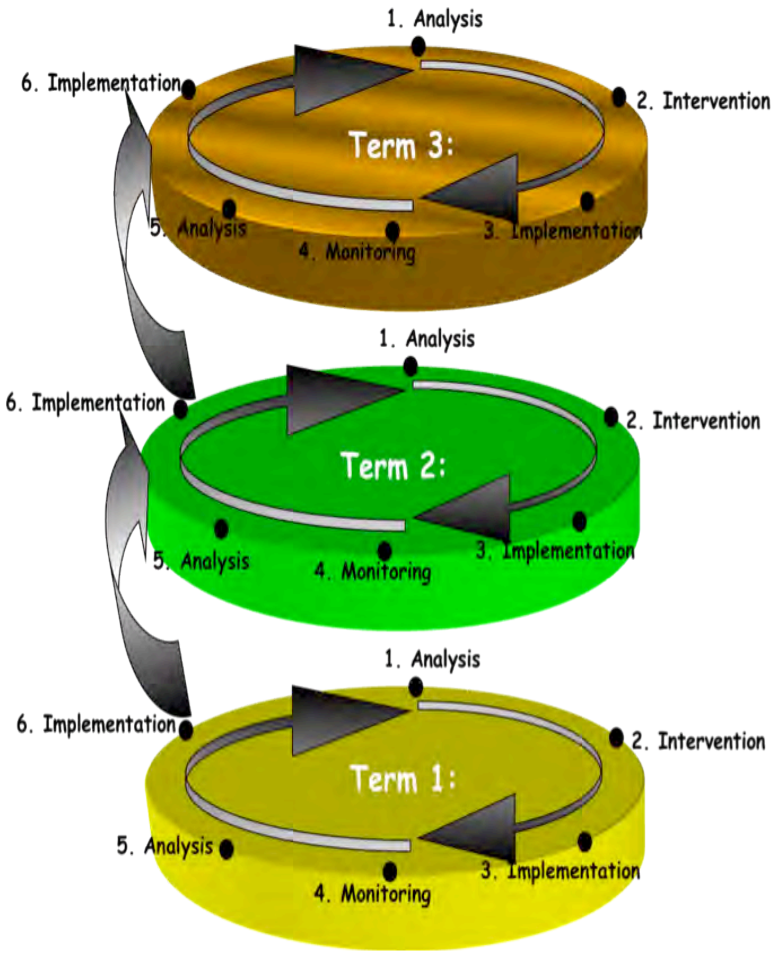
One of the main differences between action research and traditional forms of research is that in the latter the researcher is required not to influence the situation being studied, whereas in the former the researcher intentionally sets out to change the situation being studied (Lomax, 2002). In action research theories are not constructed independently and applied to the practice, instead they are generated within and through the practice (Elliott, 1991). Action research is ‘applied’ enquiry *with* people, rather than research *on* people (Altrichter, Kemmis, McTaggart, & Zuber-Skerritt, 2002), and is carried out by practitioners who have identified a need for change or improvement within their practice (Bell, 2005; Carr & Kemmis, 1986; Elliott, 1991).

As both the practitioner and the research participants join together to contribute to the process, these partners create a powerful research team (Greenwood & Levin, 2005). Fundamentally action research aims at changing three things, practitioners’ practice, their understandings of their practices, and the conditions in which they practice (Kemmis, 2009). When attempting to improve practice both the process (teaching) and product (outcomes) need to be reflectively appraised (Elliott, 1991). Action research may be used in almost any setting where a problem involving people, tasks or procedures requires a solution or a change of element to bring about a better outcome (Cohen, et al., 2000). Since a major aim of action research is to develop the situational understanding of the practitioner (McNiff, et al., 2003), it can also create a powerful means of professional development (Somekh, 1995). One such development is an improvement in the practitioner’s capacity for discrimination and judgment in particular and complex human situations (Elliott, 1991). “The ultimate goal of action research is the ability to transform” (Servan, Soto, Murillo, Sola, & Perez, 2009).

Action research normally starts with the asking of practical questions arising from concerns to do with the researchers everyday work (Somekh, 1995). One of the main aims of action research is to improve and maybe solve these immediate and pressing day-to-day real life problems of the practitioners (Greenwood & Levin, 2005), where such research does not have the writing of research papers or other publications as its primary goal (McKernan, 1996). Elliott (1991) reinforces this view, explaining that the fundamental aim of action research is to improve practice and not the generation of knowledge. The production of knowledge being subordinate to and conditioned by this aim (Elliott, 1991). Another aim of action research and one that fits well with apprenticeship education and PBL is the development of practical situations and competencies of the participants (Altrichter, et al., 2002).

The very nature of action research is to explain and deepen the understanding (Somekh, 1995) of the pedagogical assumptions of the researchers (participants) and their research project (Altrichter, et al., 2002), thus bridging the gap between research and practice (Somekh, 1995). When an action research project is complete and the findings have been considered, the job is still not finished, as participants continue to review, evaluate and implement improvements to their practice in a continuous cyclical process (Bell, 2005). As discussed in section 2.3.7 of Chapter Two, action research is a reflective cyclical or spiral research process (Opie, 2004) with a proactive orientation (Dick, 2002).

This central reflective action research cyclical process (Carr & Kemmis, 1986) starts with the analysis of the problem, which may revolve around the implementation of a new learning and teaching strategy (Cohen, et al., 2000; Opie, 2004). From this analysis a suitable intervention is then adopted (PBL in the case of this study) and monitored using a variety of research methods (e.g. questionnaires, observations, focus group interviews) (Opie, 2004). The findings will then be analysed, evaluated and reflected upon where any new or further interventions or improvements will be identified and implemented for the whole cyclical process to begin again. In the later cycles, action research continually refines the methods, data, interventions and analysis in the light of the evidence and understanding developed in the previous cycles (Earl-Slater, 2002). This involves going through a sequence of different perspectives where each perspective is informed by those preceding it (Browne & Jones, 2001). In the case of this research study, the cyclical process was run over three apprenticeship terms, of eleven weeks each and is shown graphically below.



Action Research Cycles run over Three Eleven-week Terms.

Unlike traditional research the validity of action research does not depend on measuring the frequency or extent of a phenomena over a period of time (Somekh, 1995). Instead it is more concerned with exploring the multiple determinants of actions, interactions and interpersonal relationships of people in unique contexts (Somekh, 1995). This validity is further tested by the evaluation and analysis of the impact that each refined cyclical phase is having upon the actual problem (Greenwood & Levin, 2005). Action research uses many of the same data analysis methods and techniques as traditional qualitative research (Miles & Huberman, 1994). These methods that include questionnaires, diaries and focus groups are discussed in more detail within section 4.2 of Chapter Four.

Although gaining international recognition, action research methodology does not have one widely accepted definition (Altrichter, et al., 2002), but this is justified as it takes widely different forms and is grounded in the values of the individuals and groups who participate in it (Dick, 2002; Somekh, 1995). Elliott (1991) however, offers a definition that may reflect aspects of all forms of action research as; "the study of a social situation with a view to improving the quality of action within it".

Although all forms of action research share common characteristics there are some variations or styles of its practice. Kemmis and McTaggart (2005) describe a number of broad types of action research, including participatory research, critical action research, classroom action research, action learning, action science, soft systems approaches and industrial action research. The use of each of these forms of action research will typically depend on such issues as the kinds of people involved, the kinds of environments or contexts in which they occur and the nature of the problems they are trying to address (Kemmis, 2009; Rowley, 2003).

Beyond the above types or forms however, there are also differences in the general purposes that different kinds of action research projects serve (Kemmis, 2009). Carr and Kemmis (1986) distinguish these differences as falling into three action research categories described as follows.

1. Technical Action Research:

- Is guided by an interest in improving control over outcomes.
- Aims are to improve the outcomes of his or her practice.
- Used typically to improve test scores for students in a class.
- Focus of the attention remains on the practitioner.
- Others involved are treated in the third person – as objects of the practitioners' action.
- Research decisions are made in a one-way relationship by the practitioner

2. Practical Action Research:

- Is guided by an interest in educating or enlightening practitioners so they can act more wisely and prudently.
- Also self-directed but within which others involved also have a voice.
- Treats others not as objects but as subjects capable of speech and action.
- Others involved are treated in the second person (as 'you').
- Practitioner is open to the views and responses of others (i.e. parents and students views).

3. Critical Action Research:

- Is guided by an interest in emancipating people and groups from irrationality, injustice and harm and suffering.
- Research is undertaken collectively by people acting together in the first person (i.e. plural as 'we' or 'us')
- Research decisions and evaluations for change are made collectively.
- Findings are perceived as being socially constructed.

The above breakdown adapted from Kemmis (2009), shows the varying styles or approaches within each of the three categories. I have found, through reflection of my own epistemological assumptions, theoretical perspective and fundamentally based around the research question, the approach that best describes and most suitably fits with this project is the emerging methodological paradigm of critical participatory action research (Kemmis & McTaggart, 2005). This methodological position takes into account the key features of both critical and participatory action research as described below.

Critical action research is seen as a politically empowering process that has strong representations in the literature of educational action research (McKernan, 1996). It emerges from dissatisfactions with classroom action research that tends not to take a broad view of the relationship between education and social change (Kemmis & McTaggart, 2005). It also has a strong commitment to participation as well as to critical social science as discussed in section 3.6 above.

According to Morton and Wilkinson (2008), through the 1990's, participatory action research has evolved as a methodology for intervention, development and change within the built environment. This type of action research enacts systematic inquiry in ways that are democratic, empowering and life-enhancing (Stringer, 2008). This accepted research approach involves all participants actively examining together a problematic situation with a view to change and improve it (Morton & Wilkinson, 2008). Participatory action research is a self-reflective cyclical spiral as illustrated above with such key features as:

- Participants have a strong sense of development and evolution in their practices, understandings and situations in which they practice.
- Co-participants undertake research collaboratively in the research cycle.
- Participants undertake their research as a social practical process of collaborative learning.
- Involves the investigation of actual practices with particular people in particular places.
- Participatory action research is emancipatory.
- Participatory action research is critical.
- Participatory action research aims to transform both practitioners' theories and practice and the theories and practices of others.

  (Morton & Wilkinson, 2008)

The merging of both critical and participatory action research into the specific methodology of critical participatory action research has focused this action research methodological process from the general into a more tangible and specific form. It has I feel, enabled a deeper level of understanding and reflection on each aspect of the research development to be achieved. This may further reflect a better quality of data that can be extracted and analysed from the research project as a whole. Critical participatory action research has proved in many studies, to be a means by which people have transformed their worlds and as such there continues to be a need for this research (Kemmis & McTaggart, 2005).

Action researchers take on the task of making informed choices in practice themselves (Smits, 1997) and base their decisions for action on what they believe to be of the pedagogical good (McNiff, et al., 2003). Because of this massive responsibility McNiff, et al., (2003) asserts that they always need to check if their values are justifiable and whether there influence is benefiting other people in ways that these people also feel are for their good. These and further ethical issues concerning action research in general have been discussed in more detail within section 1.5.1 of Chapter One.

3.9 Research Methods

Methods should be free from ontological and epistemological assumptions, the choice of these should be led by the research question (Grix, 2002). A prominent feature of qualitative research in education is its use of interpretive methods, which investigate the history, meanings, beliefs, values and discourses that human beings employ in the production of social life (AERA, 2009). Qualitative research is concerned with the nature of human experiences and what these phenomena mean to individuals (Draper, 2004). Qualitative research tends to start with 'what', 'how' and 'why' type of questions, rather than 'how much' or 'how many' questions normally posited within quantitative research (Draper, 2004).

This is a critical theory action research study using a variety of methods for qualitative data collection, analysis and evaluation. The purpose of action research and the subsequent analysis and evaluation of the data is to make recommendations for change that may lead to improvements in the learning and teaching of applied mathematics to student apprentices. The various research methods used within this research project, the rationale for their use, and the framework used to analyse the data extracted from them are fully listed and discussed within Chapter Four.

3.10 Chapter Summary

The start of this chapter gave a brief description of educational research in general and also outlined the different methodologies using quantitative or qualitative research methods. The importance of the ontological and epistemological position of the researcher was also discussed showing the link between these philosophical assumptions and the various theoretical perspectives or research paradigms. Each of these main epistemological categories has been elaborated upon and shown in diagrammatical form. Further to this, a breakdown of this researchers positionality was fully discussed and linked to the research paradigm of critical theory and action research methodology. In addition to this discussion the organisational and theoretical research path of this project is also shown in diagrammatical form.

Along with a description of the researcher's ontological and epistemological position within this chapter, it was also felt necessary to examine in detail my own theoretical perspective of critical theory along with the action research methodology.

At the start of any research project Crotty (1998) suggests that the following four questions must be carefully addressed:

- What methods do we propose to use?
- What methodology governs our choice and use of these methods?
- What theoretical perspective lies behind the methodology in question?
- What epistemology informs this theoretical perspective?

As the responsibility for justifying and constructing a rationale for the chosen methodology & methods (Opie, 2004) and also for demonstrating rigour in their theorising and practice lies firmly on the shoulders of the researcher (Sikes, 2004). I feel that this chapter has adequately addressed the above criteria.

Chapter Four

Presentation of Findings

4.1 Introduction

This chapter will present the qualitative findings from the data collected throughout the three cyclical phases of this action research project. These findings or ‘claims of knowledge’ need to be supported by validated evidence, generated from quality data collected during the research process (McNiff & Whitehead, 2006). Qualitative research methods normally involve the systematic collection, organisation, interpretation and analysis of textual material derived from talk or observations (Malterud, 2001). “Interpretation means attaching significance to what was found, making sense of findings, offering explanations, drawing conclusions, making inferences, considering meanings, and otherwise imposing order on an unruly but surely patterned world” (Patton, 2002, p. 480). Qualitative research, as discussed in Chapter Three, also has the unique objective of facilitating the meaning-making process (Krauss, 2005). From each cycle of this research project the data used for analysis was collected from the following sources.

- Start of term questionnaires
- Observational diaries
- Reflective diaries
- End of term questionnaires
- Focus group sessions

The qualitative researcher has the task of constructing meaning, and this should reflect the specific methods used to collect the data and the analysis process (Krauss, 2005). The reason for selecting the above methods was to provide the data required to produce a complete piece of research and also provide a degree of triangulation (Bell, 2005). The above methods were critically analysed and individually crosschecked with each other using a framework adapted from Miles & Huberman (1994). This is further discussed in section 4.2 below.

Data were also grouped as a whole term and then compared to each of the other three terms when any interventions were also analysed. This critical analysis of all data was done in an effort to maintain reliability and validity within the research process. In choosing the above research methods guidance was also sought from the American Educational Research Association's (AERA, 2009), '*Standards for Reporting on Humanities-Oriented Research*' publication. Within this document it is recommended that the research methods used should be well identified, appropriate and suitable to accomplish the overall aims and be applied in an effective manner (AERA, 2009). Each of the selected research methods (questionnaires, observational diary, reflective diary, focus groups,) is further discussed below.

4.1.1 Questionnaires

Using questionnaires to gather data is probably the most common method used in research (McKernan, 1996). Questionnaires disseminated at the start of term, were designed to get an idea of students' perceptions and feelings on mathematics in general, and more specifically on applied craft calculations. They were also used to find out how students felt about their prior mathematical learning experiences in either Junior or Leaving Certificate level and also in phase four of their apprenticeship. The end of term questionnaires were designed to get an evaluation of students' perceptions and feelings on mathematics having gone through the course using project-based learning. Some of the questions at either end of the term were repeated in order to reflect any changes of opinion or feeling that may have occurred during this period. The justification for using both sets of questionnaires (Appendix 12) was that they are regarded as one of the most reliable and valid research methods available (Opie, 2004).

4.1.2 Observational Diaries

The author's observational diary was used to reflectively record the response to, and the engagement levels with, project-based learning within the classroom. Observation is a fundamental activity associated with action research and is a requisite tool for scientific enquiry (McKernan, 1996). It can often reveal characteristics of groups or individuals that may have proved impossible to discover by other means (Bell, 2005;

Stringer, 2008). With this aspect of the research it was intended to observe and record the behaviour of the group and also that of individuals towards the process rather than the product. Daily classroom student feedback and individual comments were also recorded in these observational diaries. It was thought that this type of unstructured observation using narrative data such as anecdotal records and diaries (McKernan, 1996) was a valuable resource for recording the levels of motivation, enthusiasm, activity, non-activity and interaction of students during this project. It was also a means of capturing significant events (Bell, 2005) or critical incidents (Angelides, 2001) that occurred during the research process.

As both action research and project-based learning promote contribution and interaction from the researcher/lecturer, a participant style of observation was adopted for this research. In order to maintain a large degree of objectivity the *observer as participant* (Opie, 2004) style of observation was thought most appropriate in this project. With this style the observer interacts with the subjects but does not take on an established role within the group (Opie, 2004). "Participant observation bears the highest fidelity with the methodological purpose of action research and is the foremost technique for use in the study of classrooms and curriculum" (McKernan, 1996, p. 63). It was also thought that using an observational aspect to the research might help to validate answers to the questionnaires and focus group interviews. The observational diary used for this research project covers events from eighteen classes spread over three apprenticeship terms.

4.1.3 Reflective Diary

Reflective diary reports are important to the validity of a research project (Somekh, 1995). In this project a reflective diary was used separately from the observational diary for the purpose of recording interventions that I thought might be appropriate to introduce into the next cycle of the action research process. This meant further critical analysis of the above methods after each stage of the research process. I also thought it important to record my own personal feelings during each phase of the research project to form a self-evaluative account of the action research and project-based learning process. This also provided evidence of my own learning and indicated connections between the actions and outcomes (McNiff, et al., 2003). Since all parts of this research project are linked to one another, any ethical considerations discussed in Chapter Two also pertains to the analysis stage of the research (Boeije, 2010). Therefore, any ethical and reflexivity issues arising were also recorded in this diary for appropriate action to be put in place.

4.1.4 Focus Group Interviews

In the 1980's there was considerable growth in the use of interviews in educational research and they are now generally accepted as a critical method of qualitative data collection (Berry, 1999; Kamberelis & Dimitriadis, 2005). Because this type of research always aims to be educational, (McNiff, et al., 2003), focus groups tend to be used in action research (Dick, 2002), and for research on social issues (Hart, 2005). With reference to this research literature focus groups were considered as the most appropriate type of interview technique for this study.

Above all, focus groups are a qualitative research method (Morgan, 1998). Based on interviews, focus groups are facilitated group discussions in which an interviewer asks a series of questions of a group. The group members then provide a response to the question, and a discussion ensues ("Action Research Resources," 2009). There are many decisions to be made when implementing a successful focus group, such as, assembling willing participants, forming effective questions, gathering and analysing the data for valid results (Seggern & Young, 2003). What the group participants say during the course of their discussions provides the essential data to be collected in focus groups (Morgan, 1998). Video and audio recordings are what provide the richest of information for the study of this talk (McNiff & Whitehead, 2006; Perakyla, 2005). The main aim of focus group interviews is to understand, and explain, the meanings and beliefs that influence the feelings, attitudes and behaviours of individuals (Rabiee, 2004).

The focus group interviews used in this research project followed the questionnaires and observational data in an effort to add 'depth to breadth' (Hart, 2005) and also to record some deeper personal reasoning. Focus groups are valuable when in-depth information is required about how people think about a topic and their reasoning about why things are as they are, and why they hold the views they do (Bell, 2005).

Another reason for choosing focus-groups was that the results of these sessions can be presented in uncomplicated ways using the language of the participants (Rabiee, 2004).

Over the course of an eleven-week apprenticeship term, one gets to know individual students quite well. From this acquaintance, a group of six participants whom I felt would be willing to discuss their feelings were selected from each class. As each participants willingness to partake in the group is crucial (Morgan, 1998), all individuals were asked if they would be agreeable to take part in the focus groups. Deciding on the right number of participants is a balance between having enough people to generate a discussion and not having too many that some members feel crowded out, groups of between six and ten usually accomplish this (Morgan, 1998). The six participants chosen for each of the focus groups in this study was thought small enough to generate good conversation and an in-depth understanding of what participants had to say, yet big enough to represent a cross section of the whole participating class of sixteen students.

A week before the focus group session, participants were issued with a consent form (Appendix 6) that outlined the purpose of the research, their freedom to withdraw from the interview and a guarantee of confidentiality and anonymity. Each focus-group session has been recorded, transcribed and subsequently reported upon. While there is some literature expressing the negative effect that recording equipment has on the natural behaviour of participants, studies such as Speer & Hutchby (2003) suggest that a tape recorder is not necessarily a determinate and negative force. They also conclude that “recording devices are not automatically significant and imposing, nor do they inevitably encourage only certain kinds of talk” (Speer & Hutchby, 2003). I have also found that the presence of the recording device seemed even less significant or noticeable in the focus group settings.

Another reason I have chosen focus groups over one-to-one interviews is because I felt that student apprentices would be more confident and forthcoming with their thoughts in the company of their peers. I also felt that this type of interview technique would overcome barriers associated with direct questions and encourage an honest and descriptive analysis of the respondent’s feelings and thoughts on the topic.

It was also my intention to encourage debate and interaction between the participants and record these experiences. Individual interviews can strip away these critical interactional dynamics that constitute much of social practice and the meaning making of these experiences (Kamberelis & Dimitriadis, 2005). One of the most meaningful learning outcomes comes from listening to and transcribing these recordings from the focus groups (Krueger, 1998). I have gained from this experience by transcribing all of the focus group recordings personally. This was also done in an effort to achieve a high standard of qualitative data analysis.

4.2 Qualitative Data Analysis

Qualitative analysis transforms data into findings (Patton, 2002) and is one of the most difficult and yet crucial aspects of qualitative research (Basit, 2003). The collection of the above data through questionnaires, observation and focus groups means very little until it is analysed and evaluated (Bell, 2005). Most qualitative researchers carry out their own data analysis as it is a dynamic, intuitive and creative process of inductive reasoning, thinking and theorising (Basit, 2003). Category formation represents the heart of qualitative data analysis (Creswell, 1998). As this is an action research project, the analysis of qualitative data continued throughout the life of this project and was not a self-contained phase of its own. While there are electronic packages available such as NVivo to categorise and code qualitative research, these were not used for this small-scale project. Therefore, the qualitative data collected for this study has been manually categorised, segmented, coded and summarised using a framework adapted from Miles & Huberman (1994) for inclusion in the findings.

Coding is seen as the most important aid in conducting an analysis and is used to segment and reassemble the data (Boeije, 2010). “Coding has a crucial role in the analysis of this data and above all it allows the researcher to communicate and connect with the data to facilitate the understanding of the emerging phenomena and to generate theory grounded in the data” (Basit, 2003, p. 152). In selecting the above research methods the aim was to choose those that were suitable for this particular project and were readily analysed, interpreted and presented (Bell, 2005).

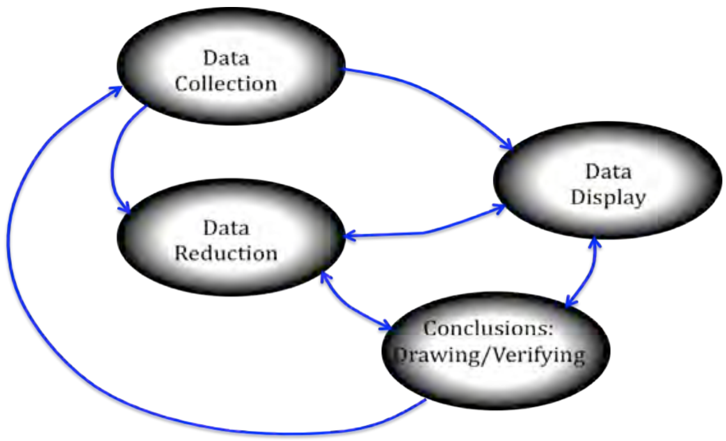
For this small-scale research project I have found it useful to adapt and use Miles & Huberman's (1994) framework of qualitative data analysis. They define qualitative data analysis as consisting of three concurrent flows of activity;

- ***Data Reduction***; which refers to the process of selecting, focusing, simplifying, abstracting and transforming the data that appear in written-up notes or transcriptions. This is part of analysis.

- ***Data Display***; is an organised compressed assembly of information that permits conclusion drawing and action. This is part of analysis.

- ***Conclusion Drawing and Verification***; are the meanings emerging for the data that have to be tested for their plausibility, their sturdiness, their conformability, which is in effect their *validity*.
(Miles & Huberman, 1994)

These three types of analysis activity and the activity of data collection itself can be shown graphically to form an interactive cyclical process. This is also particularly suitable to the cyclical nature of action research. The researcher steadily moves between these four 'nodes' to make up the general domain called 'analysis' for the whole of the study (Miles & Huberman, 1994).



The use of the above framework is also recommended by Wellington (2000) as being one of the really valuable and practical guides to qualitative data analysis. Some further guidance on the analysis of the focus group data and results was taken from Krueger (1998), who also considers data analysis as a fluid process rather than a series of isolated tasks. Reinforcing this view he makes the point, that although some steps occur simultaneously, there will be a need to loop back and repeat an earlier step similar to the above diagram (Krueger, 1998). This involves constantly moving back and forth between the phenomenon of interest and our abstractions of that phenomenon (Boeije, 2010; Patton, 2002). Basit (2003) also supports this view, emphasising that data analysis is not a discreet procedure carried out at the final stages of a research project, but is an all-inclusive activity that continues throughout the whole life of the project.

4.2.1 Reflexivity

Within my role as participant observer during the course of this study, I needed to be aware of any impact that I may be having on the research environment. In an effort to ensure that this does not affect the validity of the project, Wilson (2004) asserts that this must be met by ‘reflexivity’. This is the process of reflecting critically on the self as researcher (Guba & Lincoln, 2005) and to report what the researcher’s impact is, it being contrary to the essence of action research to eliminate it (Cohen, et al., 2000; H. N. Wilson, 2004). Participant researchers need therefore, to apply to themselves the same critical scrutiny as they are applying to others in the research (Cohen, et al., 2000). This allows researchers to reflect upon, and even celebrate, their key roles as contributors to, and participants in, their educational research projects (Morrison, 2002). With action research one must be aware that even with careful reflection it is easy to attach extraneous pieces of technique, personal beliefs, ideology, and collected experiences that may affect the validity of the research process (Hillon & Boje, 2007). It was therefore important for this researcher to assess the effects that this was having on the research process and include these findings in the discussions. Subjectivity can arise when the effect of the researcher is ignored or goes unreported (Malterud, 2001).

4.3 Action Research: Qualitative Data Presentation

4.3.1 Student Questionnaires (Cycles 1, 2 & 3):

The initial student questionnaires were designed to get an understanding of the feelings and perceptions of the students participating in the research on the subject of mathematics in general, and more specifically on applied craft calculations. The initial questionnaires in the three action research cycles, comprised of twelve questions, and were completed anonymously by 100% of the sixteen respondents in each of the participating groups. These initial questionnaires were also designed to link with the end of term questionnaires to establish if students' perceptions, confidence and understanding of applied calculations and mathematics had changed over the course of the apprenticeship term. Both sets of questionnaires were further linked to focus group interviews where responses to questionnaires could be further discussed and elaborated upon.

A graphical and descriptive representation of the initial and end-of-term questionnaires for each of the three cycles has been included in (Appendix 17) to give a visual presentation of the questionnaires findings and not for any quantifiable research. These questionnaires were further categorised, coded and combined with findings from the observational and focus group data. Analysis, reports and findings from this cumulative data are included in Section 4.4. Further to this, a discussion of the research findings from a gathering of all three of the action research cycles is included in Chapter Five.

Some interesting data emerged from the start of term questionnaire responses in comparison to the end of term responses. As mentioned earlier the end of term questionnaires were designed to get an evaluation of students' perceptions and feelings on mathematics having gone through the course using project-based learning. Some of the questions at either end of the term were repeated in order to reflect any changes of opinion or feeling that may have occurred during this period.

The questionnaires indicated that the mathematical understanding and confidence levels of the participating students appeared to have increased over the eleven-week period of each term. Most of the responses also indicated that each group would now be more confident using mathematics in their line of work having completed the PBL course. There was also a significant increase (22% to 93%) in the number of students who felt that they could now use calculations to design part of a heating and plumbing system. There were also positive results and reactions emerging from the questionnaires in relation to the levels of enjoyment and knowledge gained using PBL as a student-centred learning method. The findings that emerged from the questionnaires were further analysed along with the other research methods used within this project and reported upon later.

4.3.2 Observational Research (Cycles 1, 2 & 3):

As discussed previously an observational diary was kept on each of the applied mathematics and calculations classes held with each participating group of students. These classes were typically three hours in duration with a thirty minute break in-between. It was during these breaks that I compiled my observations for the first half of the session and I completed these notes at the end of each class. Some anecdotal records were also compiled during class as students worked among themselves on their projects.

At the start of the first class with each group participating in the research, I spent over an hour discussing the reasons for undertaking the research, and how it was hoped that it could help in a better understanding of the chosen subject. This discussion was very much a two-way dialogue where students were encouraged to put forward any thoughts and ideas on how we might best progress the research together as a single group. There was general agreement that this was a good idea and the students seemed more than willing to participate when they understood the clarity of the intended learning direction and outcomes.

At the start of each cycle, each student was given a written description of the intended research proposal (Appendix 4). This included the reasons for undertaking the research and the learning outcomes anticipated in the process. This cover letter was written in an easy to understand format that also included advice on each participant's right to withdraw from the research process.

To start the whole process each participant was given the plans, sections and elevations of a typical two storey residential dwelling (Appendix 13). Accompanying these were the first project calculations sheets, which included applied plumbing calculations to be worked out and incorporated into the house plans (Appendix 14). The first project concentrated on applied plumbing calculations from the FÁS curriculum on the topics of area, volume and capacity. Initial formulas and mathematical techniques were first discussed using the white-board before students were then asked to incorporate all of the tasks into a practical plumbing design within the dwelling.

The same format was applied to the remaining PBL classes where all of the applied calculations from the FÁS curriculum were incorporated within the same project. By the end of this process students could physically see the results of their mathematical calculations applied to a real plumbing designs within the project dwelling.

4.4 Action Research: Cycle 1: September 2009 – December 2009: Qualitative Data Presentation

4.4.1 Observational Research (Cycle 1):

My initial reaction to this new learning and teaching method was that the entire dynamic of the class changed almost immediately. Typically in previous maths classes although there were indeed some levels of interest, most of the students were very quiet, non-participative and did any handout calculations based on the theory just explained in the lecture. With the introduction of PBL however, this changed to a much noisier environment with students talking to each other (mathematically), seeking advice from me, and showing a high level of knowledgeable interest in the tasks set out in the project.

For this first project, students were interactively applying calculations for area, volume and capacity to real life working situations. These along with other questions and tasks set out in the project were designed to simulate the many typical plumbing scenarios where simple area and volume calculations can be applied. From my observational notes on this first class I have recorded that,

> This is a much busier classroom environment than previous mathematical classes I have experienced. There is much activity and interaction between students and there appears to be a level of enjoyment in the clear knowledge of why they are doing these calculations. After a period of about thirty minutes I was able to step back and watch as these group of students began teaching each other and engaging in mathematical conversations that I have not previously experienced. There appeared to be a deeper level of interactive self-learning taking place within the group. This also gave me the time to interact within the group and in particular on a one-to one basis with any students needing clarification on a particular point. This class appeared to go quicker than any previous maths class I have had. (Observational diary 30th September 2009)

From an anecdotal record of the same day I commented on the enjoyment that many of the students were deriving from talking about the results of these plumbing calculations, and in particular when one student ordered enough concrete to fill the whole room instead of just covering the under-floor heating! On realising his mistake through interaction with another student he commented, *"I will never make that mistake again"*. My observational record of the first project-based applied calculations and mathematics class recorded that these students seemed very capable of self-directed learning and also learning from each other.

In total within the PBL classes I introduced four separate projects that incorporated applied calculations from the FÁS curriculum, which were then also incorporated into a practical plumbing design within the project dwelling. These calculations were sometimes expanded but typically ranged from,

- Area, Volume and Capacity
- Heat-loss calculations, radiator sizing and selection
- Boiler sizing.
- L.P.H.W pipe sizing
- Intensity of pressure and total pressure calculations
- Power requirement calculations

My observational diary records from the first cycle of this action research project generally reflect very positive learning outcomes and a high level of interactive self and peer learning emanating from each session. I felt that the students took well to this paradigm and generally appeared to be enjoying learning how these calculations could be easily incorporated into some of their daily work on site.

From my cycle one observational notes I have also documented that although the group of students fully engaged with, and commented favourably on this learning and teaching technique, there were also some concerns expressed coming up to the end of term. These concerns were based on the FÁS end of term plumbing assessments as discussed in Chapter One. Although the students were in favour of this learning and teaching technique and had done much work on the projects up to now, it was outside the control of D.I.T to formally assess these. Instead, students have to sit the end of term summative assessments, which had the effect of reducing the interest levels for the project work coming up to week nine of the eleven-week programme. However, students studying past paper summative assessments commented that they found their understanding of the mathematical questions had improved having spent time on the project work. One of the difficulties with action research is keeping participants involved over a long period (Morton & Wilkinson, 2008).

4.4.2 Reflective Diary (Cycle 1):

As mentioned above, this diary was used for the purpose of recording interventions that I thought might be appropriate to introduce into the next cycle of the action research process. Having gone through cycle one and with cross-reference to my observational diary, the questionnaires and the focus groups, I felt that some interventions were necessary. Firstly, having distributed the plans, elevations and sections of the project dwelling it was obvious that many of the students had never looked at, or worked from architectural drawings before. Although the majority of this group were capable of working from the plans, most found it difficult to switch between plan, elevation and sectional drawings. For this reason it was thought more appropriate to issue only the plans for the next research cycle, along with a data sheet to inform on the missing sectional and elevation dimensions.

Secondly, with the concerns expressed above regarding the end of term summative assessment, I thought it worthwhile to incorporate past paper examination questions into the project-work in the latter stages of the second cycle. I believe that this was important for maintaining the motivation of the students and their perception to the learning outcomes.

From a personal learning aspect, this reflective diary has enabled me to record my own personal feelings during cycle one, and also form a self-evaluation account of the experience. From my reflective notes, the data suggests that although there are some areas of improvement necessary for the next phase of the research, the main aims relating to the implementation of a PBL approach were achieved in a way that most of the students engaged with and enjoyed. It was also an enjoyable learning experience for myself, and throughout this section of the research I found that I was much busier in class facilitating the process, and also compiling the project-work and personal reflective documentation. No ethical issues arose during the first cycle of the research, but continual monitoring of this aspect was essential for good research standards to be maintained.

4.4.3 Focus Group Interview (Cycle 1):

The first focus group interview was held in a classroom familiar to the students in D.I.T Linen Hall on 2nd December 2009. There were six participants present at this interview. I have found the interactive nature of action research to blend in well with the similar characteristics of PBL. From so much interaction with students one gets to know suitable candidates very well. This enabled me to carefully choose students whom I believed would express their feelings freely and who would also represent a cross-section of the entire participating group. A set of pre-prepared questions formed the basis to prompt the discussions (Appendix 15). This particular focus group interview lasted one hour and twenty minutes.

While the pre-prepared focus group questions were designed to link into the previous questionnaires and observational records there was no strict pattern as to which direction the discussion might proceed. The group of participants talked very openly and honestly about their feelings on the research, on PBL, and also of their feelings on learning craft calculations and previous mathematical experiences in general. They also expressed their views and feelings on learning other subjects in their trade and put forward ideas they thought might improve their learning experience. The age profile of the participant group that represented the class ranged from 18 to 41. Along with the observational data, I have found this research method to be very valuable in content and quite relative to the subject matter. A discussion of the findings from this focus group and all other research methods used in cycle one are included in section 4.4.4 below.

4.4.4 Action Research: Cycle 1: Discussion of the Research Findings

From all of the data displayed in Section 4.4, I have used Miles & Hubermans (1994) view of qualitative data analysis for data reduction, data display and conclusion drawing and verification. For this process it meant critically analysing all of the data as a whole, categorising events, finding similarities and coding the data collected from the various methods to form triangulation and verification. A discussion of these findings from the first cycle of the research is as follows.

From the research data collected it is evident that most of the group chose not to study any form of craft-related mathematics since phase four of their apprenticeship education and training. The focus group interview resulted in most participants reporting that they had not studied craft calculations since phase two. The reasons for this at the early stages of the research was not evident as most of the participating group suggested that their level of mathematical ability was between average and good. Most of this group had also completed the Leaving Certificate examination. However, further analysis of the data suggests that although their mathematical ability was sufficient to learn mathematics, the relationship between these calculations and real world plumbing tasks was not evident to most students. Student E in the focus group session commented that, '*I always had the ability to do maths in my trade exams, but I didn't know why I was doing them*' there was general agreement with this from the group where student C also reported that '*I didn't have a clue where in plumbing or on site these maths could be used, they were just written on the board and we were told to follow them'*. There seemed little reason then for these students to continue with any craft calculations or mathematics when they could see no practical reason to do so. From the projects that these students produced, to any of the data analysed, it appears reasonable to suggest that most of the student apprentices have the ability to learn craft calculations and are happy to use them where they can see a clear practical purpose to do so.

At the start of this research cycle there were mixed feelings regarding the importance of mathematics in their trade, with some students expressing views that they would never use them. However, observational data, end of term questionnaires and focus group recordings all point to a stronger level of importance attached to craft calculations at the end of term. The data also shows a more confident outlook on the use of mathematics and an interest in learning more about craft calculations and design in the future. There was a general feeling that having gone through the PBL method of doing applied mathematics that they could now use this knowledge and apply it to a real plumbing design. Student F commented that "*I could now see what the maths were doing in the project house, it's more like what we're used to being a plumber*".

Regarding PBL there was general consensus among the group that this was a much better mathematical learning experience than they had previously had. Many students expressed that they had enjoyed the learning experience and thought that other subjects should also be delivered in this manner. During the focus group interview, I found it most interesting to listen to this group of students still discussing with each other, the mathematical formulas they had used in the various projects a number of weeks previously. When questioned on this they expressed an ease of understanding having used these formulas to produce an end product. Student A made the point that, "*when I did heat-losses before I finished with a number that meant nothing, this time I had to go and find a radiator to match and also make sure it would fit in the space, now it means something to me*". Most of this group agreed that they could now understand these calculations better and they had also learned where they could be used within their line of work.

As discussed in Chapter One, one of the most important parts of the off-the-job phase six for the plumbing apprentice is assessment. However, the FÁS curriculum is dictating the number of subjects to be covered for the summative assessments and learners must follow suit in order to pass these examinations. From the data collated from this first phase of research, there is strong evidence to suggest that the students really wish to learn more about their trade. When given an opportunity to learn and apply it to their chosen craft they willingly undertake the tasks and are interested in coming up with a workable solution. Most of the comments relating to this in the focus group interviews and in classroom discussions concurred that studying questions and subjects for an end of term summative assessment was not increasing their craft knowledge. Student F summed up the feelings of most of the group with; "*it would have been great to do all the plumbing subjects and put them in the project* *house, I would definitely have learned much more about plumbing*". Student C followed; "*if we were assessed on this it would be much better and we would learn 100% more than trying to remember questions*". When I enquired further, and asked if this was because they thought it would be easier, all replied that, no, it was because they would learn more about their trade. Student B also made the point that; "*it would be great to see how all the different systems like heating and plumbing join up with each other in a building, at the moment we just do everything separately, it is just read out and I can never see how they all link together*".

The review of the literature in Chapter Two suggested that the majority of apprentices do not progress to further education. The data gathered from this first cycle of the research process also implies that this is the case. While most in the group were eager to carry on with courses within their craft or a craft-related discipline, few of the students in focus group interviews suggested a return to full or part-time further education.

From the data gathered and analysed over the first eleven-week research cycle, I felt that most of the aims and objectives as outlined and discussed in section 1.4 had been met. In some instances they had exceeded my expectations. The attitude of these students was, with very few exceptions, very positive throughout the course. Among the contributing factors, was the awareness that they were in charge of their own learning, along with the feeling of freedom in planning and carrying out the project-work. There appeared to be a genuine willingness and interest in learning among the student apprentices, but they need to see a relationship to their craft, and a means of applying this knowledge to real life practical situations. Most of the students in this first group also indicated that they felt they had met the learning outcomes discussed at the start of the term.

4.5 Chapter Summary:

This chapter presented the qualitative findings from the data collected throughout cycle one of the action research project. The rationale for each of the research methods used in the process has been explained in detail along with the framework used to analyse the data. Although this chapter is entitled ‘presentation of the research findings’ it also included some discussion of these findings from cycle one of the action research process. This was thought appropriate in order to develop an ongoing representation of the research process and also to begin to develop a reflective link between the findings emerging from each individual cycle. The qualitative data presented for cycle one above were also fully compiled and presented for cycles two and three and are included in (Appendix 18).

As action researchers organise their thinking in terms of what they are experiencing at that moment (McNiff & Whitehead, 2006), this chapter also allowed me to present and discuss my own thoughts and feelings initially recorded in my reflective diary. It was also thought important to allow space here for the voices of the participants to be heard and their feelings expressed. Students are capable of reflecting on, and expressing their feelings of, their experiences and actions and also communicating these understandings to evaluators, Mann (as cited in Fairtlough, 2007).

With the intention of improving each cyclical phase of the process, action research constantly evolves through the introduction of various interventions. For this reason it was regarded as imperative that a discussion of this evolutional transformation should be included after each cycle of the research. This was thought prudent to guide the reader through a more comprehensive understanding of the foundation of the findings before holistically gathering this information in a more discursive manner in Chapter Five.

Chapter Five

Discussion of the Research Findings

5.1 Introduction

In further analysis of the collated data, it was necessary to recognise that qualitative research analysis is multi-layered and may be interpreted in different, but equally plausible ways (G. Gibbs, 2007). This section therefore, intends to move from the individual cyclical presentation and data analysis of the previous chapter, to a more holistically inclusive discussion. This entailed engaging further in an intensive reading process of all of the data utilised and findings presented in Chapter Four. This has meant being 'true to the data' and the people who have provided it, in an effort to make a faithful representation of the data collected (Wellington, 2000). As the data was qualitative, no efforts have been made to quantify it beyond rough statements such as 'many' or 'few' etc.

All of the above data however, means nothing until its status is changed from individual pieces of information to a larger body of analysed data, to stand as findings of the research (McNiff & Whitehead, 2006). The validity of any such findings has, I believe, been tested by the rigorous methodological procedures and triangulation (McKernan, 1996), outlined in Chapters Three and Four, and used throughout this research process. A standard that I have maintained throughout this project can be described where Warner (as cited in Miles & Huberman, 1994) speaks of 'natural' validity – the idea that the events and settings studied in the research are uncontrived or unmodified by the researcher's presence and actions. This chapter will holistically summarise the discussions already made from each action research cycle in Chapter Four.

5.2 Reflexivity

As discussed in detail in section 4.2, I needed to be aware of the impact on the research environment that I might be having as a participant observer. In an effort to ensure that this does not affect the validity of the project, Wilson (2004) asserts that it must be met by 'reflexivity'. "Put simply, reflexivity is the recognition that the product of research inevitably reflects some of the background, milieu and predilections of the researcher" (G. Gibbs, 2007, p. 91).

During the course of this project I have used my reflective diary to record ethical issues, interventions and personal learning. Also recorded in this diary are notes of personal critical scrutiny pertaining to any affect that I may have been having as a participant researcher. As action research is about changing a particular situation, it invariably has an immediate impact on participants. As I too was a participant in the research process, this also meant a change of practice as a lecturer/researcher.

Furthermore, the very nature of PBL, allowed me to abandon the typical lecturer/student hierarchy and become more accepted as part of the research group. As explained in section 4.1.2, the *observer as participant* (Opie, 2004) type of observation was thought most appropriate within this project with the aim of maintaining objectivity. This type of observation allowed me to interact with the group without taking on an established role. With this type of participation, it appeared that my presence had little impact on the activities of the research groups. Reflexivity concerns noted within my reflective diary mainly report issues relating to motivation. On occasions I felt that I needed to interrupt the whole group and encourage some urgency to move on to the next set of tasks. Apart from such minor notes, I maintain that my presence within each participating group had little or no impact on the research proceedings.

5.3 Reasons Underlying the Choice of Research Topic

The choice of using applied calculations and mathematics, as the topic for this research project was two-fold. Firstly drawing from experience and from studies of research literature, the subject typically holds the least motivational engagement among students. It is also evident from further investigation of the literature that this is far from a local problem. Secondly, I thought choosing this topic was probably one of the toughest tests for the use of PBL. It was felt that introducing PBL for a more typical plumbing subject, where interest levels were already good, would not have been such a stringent examination of this learning and teaching method. I also thought it necessary to try and create or provide an environment that helped to motivate and engage the students, and to provide challenges based on these motivations. It was considered that PBL could help to provide such a challenging environment. The following sections report on the collective findings of these tests completed over the three cycles of the action research process.

5.4 Summary of Findings and Discussions

5.4.1 Motivation

With few exceptions, the attitude of the participating students was very positive during the course of the ten-month research period. Among the contributing factors was the awareness that the students themselves had made the choice as to the level of learning to be obtained from the projects. With the responsibility for learning now resting in their own hands, many students expressed a feeling of freedom to learn in a way that suited them best, both individually, and in consultation with their peers. Initially, for a few students, this very freedom in learning choice together with a lack of formal structure was in itself hard to deal with. With lack of experienced with this method of learning and teaching, many students seemed mistrustful of their own ability to engage in self-directed learning. McNiff & Whitehead (2006) also make the point that pedagogies tend to be didactic with very few students ever being asked in their entire school career, what they know and what they think they should learn. However, without exception, these students quickly took to PBL and subsequently reported an enjoyment in learning not previously experienced.

Most of the participating students indicated that the good atmosphere created in class was also a motivating factor towards their learning. Because this format was flexible it also enabled me to see some of the different ways in which students learn, understand, and work together to achieve successful outcomes. Often they made suggestions for change that were better than ideas I would propose. This reminded me that students are able to solve their own problems, and make their own decisions as to which learning approach to use in the process.

The highest motivational aspect to learning that emerged from the findings came from the authenticity of the projects, and their relevance to real world plumbing design work and problems. Over the course of the research it became apparent that most of the students were very interested in working on these tasks to a deep and conclusive level. The tasks were directly related to their craft, where there was a logical and practical outcome, along with a transparency as to why they were undertaking them.

One of the most interesting questions often asked of student apprentices is; 'what is their motivation to attend college for the off-the-job phase of their apprenticeship?' Over the years I have often heard it argued that it is money and not learning that is the motivational factor. Many would debate that apprentices only attend class because if they don't turn up or leave early, it is reflected in their wages. The average take home pay of a phase six apprentice during their off-the-job training is €530.00. These arguments do not put forward that student apprentices are driven or motivated by a will to acquire knowledge about their craft. I have personally always refuted this theory. Over the years I have noticed better qualities in these students when placed within engaging learning environments.

In order to test the introduction of PBL even further and in agreement with my Head of Department, it was decided that during the entire research period, participating students would be allowed to leave my class whenever they wished, without any wage deductions. To many raised eyebrows this was fully explained to all participants at the introductory stage of the research. It was further explained that the reason preferred for students to attend any PBL class was for educational purposes alone. Those who attended for monetary reasons were invited to sign-in before class and were then free to leave without any pay implications. Over the course of ten months of research with forty-eight participants, not a single student chose to accept this offer. In fact there seemed to be an opposite reaction, where many times students asked if they could extend the PBL class into the evening to complete some project tasks. It also appeared to change the attitude of many students, where before they felt they were being held in class by the clock, now it was their own responsibility to decide if they wanted to attend and partake in any learning exercises. Many students also worked on their projects at home, bringing in some very innovative designs for the following week's PBL class. From this aspect of the research it seems safe to suggest that it is not just financial gain that motivates these apprentices to attend college, but also a will to learn about their craft. However, the findings strongly advocate that the type of learning and teaching is also vital to maintain this motivation.

The greatest de-motivational factor that emerged from the findings is that of the curriculum, and the relevance of the associated summative assessment to their particular work environment. As discussed previously in Chapters One and Four, the type of didactical teaching and rote learning associated with the delivery of this curriculum does little to motivate students. Many practitioners in organised education also complain that they have to 'cover' the syllabus or 'deliver' the curriculum, the emphasis being on getting a functional job done, rather than about working with people with real lives (McNiff & Whitehead, 2006). Many students also expressed disappointment as to the low level of craft competency progression they felt they were gaining within off-the-job phases of their apprenticeship. In the current economic downturn, apprentices need to progress through their training acquiring the high skills, competencies and knowledge that employers now seek from craftspeople.

From all of the findings presented here and within Chapter Four it might, then, be concluded that PBL has raised the interest and motivational levels of these students to engage with applied calculations and mathematics. In this situation, the quality of the project planning aspect of the course was also important in order to maintain motivation.

5.4.2 Previous Mathematical Experiences

At the start of each research cycle there appeared an initial and fundamental 'concern' or 'anxiety' regarding applied calculations. From all of the research methods used, the reason that emerged most frequently regarding this apprehension was misunderstandings of exactly where these calculations can be used for real-work problems.

Many students expressed negative feelings towards the type of teaching methods they experienced in the past. They believed the lecture-centric methods they had previously experienced had led to the memorising of formulas for examination purposes, and not to any real level of understanding. Those who expressed such views also explained that because of this rote type learning, they had now forgotten most of the mathematics and applied calculations from second and third level education respectively. Further investigation and in-depth analysis of the findings during the research process suggest that this is not a 'blame game' the students are engaged in. Much of the literature would also agree as Mills & Treagust (2003), from Section 2.2.4, point out that, formal lecturing techniques are ineffective with craft classes. Technical-Education (1961), also from Section 2.2.4, further states that there is a tendency for lecturers to blame the subject of mathematics for learning difficulties or the student for lack of talent. Within section 1.1 of Chapter One Klymchuk, et al, (2008) also make the point that, to improve understanding, students need much stronger experiences in building real world and mathematical world connections. Also within Chapter One, Johnson and Fischbach (1992), argue that traditional forms of mathematical instruction seem not to have succeeded in providing the skills needed by students to solve problems in industry. Within Section 2.2.1 of Chapter Two, there is also much detailed discussion drawn from the research literature pointing to a predominately didactical educational paradigm, used to teach mathematics in Irish second level education.

From all three cycles of this research project, the findings strongly concur with such research literature. Much synthesised data collated over the research period provides strong evidence that implies low levels of mathematical knowledge gained from second level education. This was the case even though the majority of participants held a Leaving Certificate. Many students also experienced low levels of learning enjoyment while using mathematics in the past. These collective findings also hold that phase six student apprentices display an inadequate understanding, and use of, applied craft calculations and mathematics at the start of term. Most students reported the type of rote learning and summative assessments previously employed at second level had extended to both phase two and four of their apprenticeship, and did little to improve their craft mathematical skills or retention of the subject.

With few exceptions, research participants put their misunderstanding of applied craft calculations and mathematics down to learning and teaching methods utilised, where connections to real world problems were not apparent. Findings from the research literature, as in Section 2.2.4, also agree that often only spurious relationships exist between assignments and actual work tasks.

Although there was general agreement that applied calculations were an essential part of their trade, only a slight majority felt that a lack of knowledge in this area could hold them back in their future career. However, this attitude appeared to change as participants moved through the research process, and used calculations to design and solve real plumbing tasks. Over the three cycles of the research, many students also conveyed feelings of apprehension regarding their current level of craft mathematical knowledge, and the fact that this was their last off-the-job apprenticeship phase.

Further analysis and interpretation of the above findings hold that the majority of these apprentices are aware of their lack of understanding of applied calculations. In agreement with such research literature as Section 2.2.1, most participants put this down to previous didactical type teaching methods promoting the use of rote learning. However, the willingness to move on, and learn to use, applied craft calculations also emerged quite strongly and regularly from all of the findings.

5.4.3 Mathematical Learning Trends

All of the findings over the three research cycles uncovered craft mathematical learning trends that are practically non-existent among apprentice plumbers during on-the-job phases of their training. The use of applied craft mathematical skills on site was also found to be extremely low. Those who had reported using calculations on site within questionnaires later reported that it was mostly just measurement type calculations that they employed. All of the research methods used throughout show feelings of misunderstanding between applied mathematical formulas and their relationship to real world plumbing tasks. Many participants had reached phase six of their apprenticeship having never used applied calculations on site. The most common reason to emerge from the findings was that although most could learn the calculations in class for examination purposes, they were never taught how to apply them in practice. Many therefore could not see the point in learning skills that firstly they had seldom or never used, and secondly, could not envisage where they might be used in their future line of work.

Consistent findings over the research period however, show most of the apprentices are aware that applied mathematical calculations are an essential part of their craft. Most of the participants also indicated an interest in learning more about applied craft calculations and were pleased that they were included as part of the course curriculum. However, there was broad agreement that in order to be able to acquire this skill, the mathematical tasks must be challenging, link to their craft subjects and lead to practical outcomes. This also relates to views expressed by Engineers Ireland (2010) as previously discussed in Section 1.2.

From the above I found it reasonable to conclude that although many students had experienced learning and teaching styles that did not promote deep learning in the past. Most of the apprentices were eager to participate in a new learning and teaching paradigm in an effort to broaden their craft capabilities. This included a combination of the use and subsequent knowledge of applied calculations acquired through PBL. Much of the research literature also concurs, and is typically highlighted in section 1.3.1 by Haghighi, et al, (2006); that to encourage interest in mathematics, students' must get actively involved through hands-on activities.

5.4.4 Mathematical Confidence

Gaining confidence in any talent usually results in more enjoyment being extracted from it. Findings from all three cycles of the research period show that this relationship also exists with applied craft calculations. With very few exceptions students showed an increase in confidence in their ability to use and understand craft calculations over the research period. As confidence levels grew the findings also show a substantial increase in the enjoyment levels during the PBL activities. The over-emphasis on procedures and techniques as discussed by English, et al, in section 2.2.1, is removed using PBL, thus extending what he describes as the 'pleasure side of mathematics'. The use and practice of applied calculations through PBL has contributed to a distinctive increase in mathematical confidence levels over the course of the research study. With this increase in confidence, many students throughout the research period, showed initiatives to extend their mathematical skills beyond the curriculum. These findings reflect much of the research literature where typically Breen, et al, (2009), section 2.2.4, reinforces the view that; confidence in one's ability to learn mathematics has also been found to have a strong positive correlation with mathematical achievement.

5.4.5 Mathematical Understanding

One of the major aims from this research project, was the provision of a platform to enable a deeper understanding of building services applied calculations and mathematics to be achieved. In order to evaluate the effectiveness of the introduction of PBL, many research methods, as discussed in Chapters Three & Four, were employed. Primary sources of data gathered over each of the three, action research cycles came from two sets of questionnaires, observational diaries, reflective diaries, focus group interviews and personal classroom contact with individuals.

From the presentation of the findings of each individual cycle in Chapter Four, and the holistic interpretation here, the research holds that the majority of those who participated reported a distinct increase in both their level of understanding and competence, in the use of applied calculations. This was also measured through weekly submissions of tasks and problems where there was a large degree of independent learning built into the projects. Their project-work in turn acted as a test and a presentation of their learning. Also throughout the research literature, and further discussed in Section 2.3, there is much evidence to suggest that the introduction of PBL can foster deeper levels of learning and contribute to an engagement with lifelong learning.

Initial data had shown a low number of apprentices who had ever used craft calculations to design any part of a plumbing system. However, later findings revealed that with added confidence in their knowledge and understanding, most would now feel able to accomplish many design-orientated tasks and work related problems.

The feedback from the majority of students together with all of the research findings has shown that PBL, when used in the correct circumstances, has the ability to create learning environments that are facilitative to deep levels of learning and understanding. I believe that this has made the largest impact on the outcomes of this research project.

The literature review in Chapter Two revealed that most apprentices chose not to return to further or higher education. The findings of this research project agree, where only a few participants expressed a will to progress to full or part-time education in the future. However, most participants agreed that they would now have more confidence and a deeper understanding of calculations and mathematics and would consider progressing to higher craft-related courses. This research project, was compiled during a severe economic downturn where many apprentices now find themselves unemployed, and more are now seeking additional or advanced craft-related courses. However as discussed in section 1.2, options to progress through this route are quite limited at present in Ireland.

5.5 A Reflection on Aims and Objectives

Listed within section 1.4 above, are the specific aims and objectives of this research project. The specific aims for the study were based on the current apprenticeship educational paradigm, and the increasing awareness of how a different learning and teaching technique could enable a better understanding of applied mathematics and calculations. The learning and teaching technique introduced and discussed in detail throughout this study was Project-Based learning.

Listed among the main aims was ‘motivation with authentic learning’. From the detailed description given to this matter in Section 5.4.1, I believe that this aim has been achieved. The findings discussed in Chapters Four and Five also detail a learning environment created through the use of PBL that encouraged ‘student-centred learning’ and ‘deep learning’ to be achieved. The interpretation of the findings also holds that the majority of students achieved a ‘deeper understanding’ and ‘awareness’ of where craft calculations can be used in their line of work. These were some of the main aims of this action research study. Section 5.4.4 gives details from the findings in relation to mathematical ‘confidence’. From these findings I feel it is safe to conclude that mathematical confidence, understanding and enjoyment levels increased during each cycle of the research process, thus fulfilling these aims also.

In relation to progression to further education, the findings above give no increase in commitment by students to progress to further education. However, most participants were encouraged by their mathematical development to consider progression towards advanced craft courses. All but a few participating students confirmed their level of mathematical ‘competence’ had increased over the research period, with many regarding this as an extra skill they could now use as a craftsperson.

The above paragraphs, along with discussions in the previous two chapters, combine to weave the various threads of findings together, and show how the main aims and objectives outlined in section 1.4 of this study have been met in relation to the introduction of PBL. The students’ evaluation of PBL also remained very high throughout each of the cyclical phases of the research process. They indicated that among the contributing factors was the theoretical/practical aspect of the course project work. Many also felt that the acquisition of specific mathematical skills and their ability to analyse and solve tasks presented in unfamiliar contexts was a prerequisite for a comprehensive understanding. However, there was the underlying concern that the final summative assessment still tends to overwhelm students perceptions, habits, techniques and aims in relation to learning. I have often felt throughout this research process that the standards we are trying to achieve in this ‘standards-based’ apprenticeship system are being compromised through the curriculum.

5.6 Reflection on the Research Question

Over a year ago, and originating from long-term concerns I held relative to the actual amount of deep learning and understanding that students obtained from my classes, I asked myself the question; *can a deeper understanding of subjects be achieved through the implementation of a different learning and teaching method?* To go some way towards answering that query some further questions arose. Firstly, what other learning and teaching paradigms are suitable for the purpose, and is there any evidence of previous success in their use? To answer both of these questions an in-depth review of the research literature was considered as a starting point.

As discussed in detail within Chapter Three, people carry with them, certain ontological and epistemological beliefs throughout their lives. As I too carry such beliefs about how knowledge is acquired and transmitted, I needed to be careful to place the context of the research and the students' concerns foremost whilst engaged in this literature review. The literature review revealed many interesting thoughts relative to craft education and training where authentic learning appeared to surface regularly within many international journals and texts. The use of self-directed learning using real-life problems and projects was advocated not only for craft education but also for second and third level educational systems in Ireland and abroad. This has been further elaborated upon within Sections 2.2.1, 2.2.4, 2.3.1, 2.3.2 and 2.3.5 of Chapter Two. Discussed also within Section 2.3.6 of the literature review, is the integration of PBL into apprenticeship education, and how the literature indicates that this pedagogy may provide students' with a deeper understanding of their individual topics.

As discussed in detail in section 3.6, social constructionist/constructivism and critical theory, best describes the epistemological/theoretical perspective and positionality of the author. It followed that PBL, being a constructivist pedagogy and recommended through the literature, would also fit well within this framework. To adopt PBL for research into apprenticeship learning, a specific topic from the large curriculum (discussed in Section 1.3.1), was required to rigorously test the research question. As explained in Section 5.3, plumbing craft calculations and mathematics was chosen as the most suitable subject for this research project. The above research question was subsequently refined to; *can a deeper understanding and application of building services applied mathematics be achieved through the implementation of Project-Based learning within apprenticeship education?*

5.7 Answering the Research Question

This action research project was carried out over a ten-month period, using a variety of research methods to collect data, with three separate groups, (totalling 48) of participating individuals. The data was subsequently categorised, coded and analysed after each cycle of the research, using a recognised framework as discussed in Section 4.2. The data produced findings that were presented and discussed after each research cycle to provide a foundation and scaffolding to support the holistic interpretation discussed in this chapter. The individual presentation of findings in Chapter Four was also necessary to report on the interventions that were introduced, to improve each action research cycle. These interventions are most important to the evolutional progression of an action research project. As this process tends to be cyclical, it is often referred to as action-reflection cycle (McNiff & Whitehead, 2006). In addition to this, the findings from all cycles were further analysed in order to produce a complete representation from the various layers of information.

From all of the findings presented here and within Chapter Four above, I maintain that through meticulous care in the construction of this study, the research question posed at the beginning of the research work has been answered. The findings and discussions presented in detail above, along with positive feedback from students during the course of this study, leave me confident to report that I believe a deeper understanding and application of applied calculations and mathematics can be achieved through the implementation of Project-Based learning within apprenticeship education.

Like any research, this project is provisional and open to any further testing, critique or modification (McNiff & Whitehead, 2006). As discussed in section 2.3.7, this research was not intended to create an end product, but instead a work in progress that may be extended to help to improve learning and teaching practice in other areas.

5.8 Chapter Summary

This chapter has gathered together for discussion, the qualitative findings from the data collected throughout the three cyclical phases of the action research project. It has further linked these findings back through the literature and also placed them within the context of the research. The above chapter has also shown how these findings fit within the complete research design framework. Reflexivity was also discussed and how this has been addressed throughout the research proceedings.

Aims and objectives of the research, such as motivation, confidence and understanding were re-evaluated in an effort to illustrate how the research findings have culminated to meet these goals. Having demonstrated that the main aims and objectives have been met, it was then thought important to reflect on the research topic and question.

Furthermore, the personal questions that generated initial concerns when evaluating feedback in my own teaching practice were outlined above. From these questions it was shown how further searches through the literature refined the final research question that led to the introduction of PBL.

The chapter concluded with a discussion of how the research findings, holistically gathered together from all three cycles of the action research project, have demonstrated a realisation of the research question.

Chapter Six

Conclusions, Recommendations and Reflections

6.1 Introduction

For more than two decades there has been a paradigm shift in education from a focus on teaching to a focus on learning (Rust, 2002). This research project set out to investigate if a paradigm shift from teacher-centred to student-centred learning could achieve an improvement in teaching practice on behalf of the lecturer, and deeper levels of understanding and activity on behalf of the student. Student-centred learning has in theory brought about greater student participation and involvement (Taras, 2002). This paradigm shift took the form of a project-based learning pedagogy, which removed the responsibility for learning from the lecturer whilst making the students more accountable for what and how they learn (Robinson & Udall, 2006). The implementation of this pedagogy through an action research methodology was used in an effort to actively engage students in their own learning and assessment, and also to develop their higher-order thinking skills. Self-assessment is also advocated as a means to encourage students to develop critical thinking skills (Fitzpatrick, 2006). With the above objectives outlined, the topic of applied craft calculations and mathematics, within the trade of plumbing, was chosen to present learning challenges to each participating cohort. Their project-work in turn acted as a test and a presentation of their learning and understanding.

The research studied the initial knowledge state of three separate groups of phase six student craft apprentices (48 people in total) in relation to applied calculations and mathematics. Their progress through the course was subsequently monitored and evaluated through the use of project-work. Observational and reflective diaries used throughout the research process, recorded the variations in the participating students approaches to problem solving, their awareness of the learning process, and their self-assessment abilities. End of term interviews and questionnaires subsequently provided the remaining data that has been analysed and the findings presented in Chapters Four and Five above, and also from which, the following conclusions were drawn.

6.2 Conclusions

One word might probably suffice under this heading; '*assessment*', as it takes up so much time that could otherwise be devoted to learning and teaching (Boud, 2006). Often the words 'deep' and 'surface' are used to describe approaches to learning, but more precisely they are approaches to 'assessment' (Bryan & Clegg, 2006). Most students can adopt either surface or deep approaches to their learning and one of the most important influences on which approach they take is course design and assessment (Rust, 2002). It is assessment that frames learning, creates learning activity and is the driving force for motivation, types of learning and teaching, and understanding (Bryan & Clegg, 2006). In many cases it is assessment that has more impact on learning than does teaching (G. Gibbs, 2006a).

Sections 2.3.3 and 2.3.4 above also outline work on educational taxonomies, such as Biggs (1999), who advocates a more sophisticated and aligned use of assessment to support high-level learning. In order to introduce this constructivist type of learning to students, a great deal of effort and thought must be put into the curriculum. This must ensure that the learning outcomes, assessments, and the learning and teaching strategies are aligned (Holroyd, 2000; Pearson, et al., 1999). There is therefore, room to probe for alternative models for enhancing curricular coherence between what and how students learn and how they are assessed (Mentkowski, 2006). Formative and continuous assessment procedures with regular feedback to students can enhance these learning processes (Murphy, 2006). Continuous assessment with less reliance on end of term examinations, also opens greater possibilities for assessment for learning (Murphy, 2006). Throughout this research study it can also be seen that through the use of PBL along with regular student feedback, levels of craft mathematical confidence, self-directed and peer-learning, understanding, and self-assessment has improved over each action research cycle.

The research literature reviewed in detail within Chapter Two, also describes how summative type, time constrained assessments, combined with didactical teaching methods, contribute to the use of rote learning techniques by students. This in turn is contributing to what the research literature describes as the 'maths problem' both in second and third level education. As discussed in Chapter One, the FÁS phase six plumbing curriculum with two end of term summative and time constrained examinations, does not encourage students to engage in the type of 'learning by understanding' advocated throughout this recent educational literature. Subsequently, the use of rote learning as discussed many times in Chapters Four & Five is very apparent. Section 3.3.1 indicates that the high referral rates for these assessments may stem from the number of subjects that both the student and lecturer must cover from the curriculum over an eleven-week period. Also discussed in Section 3.3.1, is the pressure placed on lecturers to deliver this amount of curricular content for examination purposes, which can lead to an environment led by traditional lecture-centric teaching methods, and to surface learning on behalf of the students. The following course characteristics associated with a surface learning approach could also very well describe the current phase six plumbing curriculum shown in brackets below.

- A heavy workload
(35 hours per week)

- Relatively high class contact hours
(Weekly; 10.5 hours in practical class & 24.5 hours in theory: (Appendix 16))

- An excessive amount of course material
(30 subject areas with over 370 detailed learning points: Section 1.3.1)

- A lack of opportunity to pursue subjects in depth
(Didactical teaching methods driven by excessive course material: Section 1.3.1)

- A lack of choice over subjects and a lack of choice over the method of study
(Apprentices have no choice with subjects and because of teaching methods study patterns are predominately rote memory)

- A threatening and anxiety provoking assessment system
(T1 and T2 Summative assessments upon which final apprenticeship progression depends. Very high percentages required to pass and high referral rates: Section 1.3.1)

(G. Gibbs, 1992, p. 9)

All of the research findings reported in the previous two chapters conclude that this is not a learning environment that student apprentices want to find themselves in. The majority of participants showed high enthusiasm to learn about their craft, but most found it difficult to learn under the pressure of the curriculum content and the summative examinations. The didactical teaching methods predominately used to deliver this curriculum have also been reported to lack the linking of subjects to each other, or to any real-world craft problems or scenarios. A participant student from cycle one of the research process who was referred in the T2 summative assessment later reported; *"I was just reading and reading the stuff, but because I didn't understand what I was reading, I just had to memorise everything. When I sat the exam I was asked something different and because I didn't understand the subjects I couldn't answer the questions and failed the exam. I have friends coming over to help me to try and understand the subjects instead of just memorising it this time"*. Preparing these craft students for real-life work should involve engaging them in tasks to make complex judgements about their own work and for making decisions in uncertain and unpredictable circumstances in which they will find themselves in the future (Boud & Falchikov, 2006). This involves removing assessment from the domain of the assessors into the hands of the learners, making it an indispensable accompaniment to lifelong learning (Boud, 2000).

In contrast to the above, Gibbs (1992) gives a list of course characteristics that can foster a deep learning approach, and which today can also validly describe PBL.

- The engendering of intrinsic motivation in the students; students wanting and needing to know

(Discussed in Chapters 4 & 5)

- Learner activity

(Discussed with PBL throughout this study)

- Interaction with others

(Discussed in Chapters 4, 5 & 6)

- A well structured knowledge base – i.e. where content is taught in integrated wholes and where knowledge is required to be related to other knowledge

(Describes the interlinked project tasks outlined in Section 4.4.1)

(G. Gibbs, 1992, pp. 10-11)

The use of PBL in this action research project was to find out if a deeper understanding and application of building services applied mathematics could be achieved. All of the findings point to positive results with students reporting higher confidence levels and better understanding of the subject through the use of interlinked project tasks. Observational reports also reflect high activity and engagement levels among students when carrying out these tasks. It was also interesting to observe how critical many students were of their own work when engaged in self-assessment. From this self-assessment process even deeper levels of engagement were observed when self-corrections were required. Students engaged with PBL also got the chance to work collaboratively with their colleagues and avail of peer learning. The potential benefits of peer learning have long been recognised but many existing assessment practices act to undermine these and lead students to reject learning cooperatively (Boud, Cohen, & Sampson, 1999). The use of group projects and collaborative learning also encourages students to learn from other students as well as from the lecturer (Keppell, Eliza Au, Ada, & Chan, 2006). The motivational levels remained very high throughout the PBL classes through the use of real-life plumbing mathematical design tasks and problems that provided clear goals and immediate feedback. The focus on these tasks was towards the process of the given activities rather than the outcomes. Assessment tasks are far more likely to appear relevant if they are 'real-world' tasks, where the student can see why in the 'real-world' someone might undertake such a task (Rust, 2002).

As discussed in Chapters Four & Five, many times throughout the research process students asked, why this type of learning and teaching could not be used for all subjects. As has been shown previously, the majority of the student apprentices wish to be better craftspeople, and are eager to learn and understand more about their trade. However, many then find themselves caught up in a system driven by summative assessments and rote learning, where progression as a craftsperson appears not to be achieved to its full potential. As many students have reported; *"this is my last off-the-job phase and I feel that I haven't learned much, I have memorised enough stuff to pass my exams but that doesn't make me a better tradesman"*. Regular feelings were also expressed regarding the level of understanding that was being taken from many subjects, typically; *"if all the subjects were done through projects like these, we would learn and understand the systems and how they all come together much better, instead of being just told to keep reading our notes about stuff we don't understand"*. From the learners viewpoint, 'doing without perceived purpose' combined with a teacher-centric balance of power, discourages modern students from fully engaging with learning (Robinson & Udall, 2006).

I believe this situation is exacerbated in relation to craftspeople, where linking theory to real practical purposes has been shown to increase learning and understanding. Research evidence suggests that to increase engagement and activity levels the use of assessment strategies such as project work, group work and problem-based learning is recommended (Rust, 2002).

This research study has convinced me that the use of a student-centred learning paradigm such as Project Based Learning can go a long way to enhance the learning and understanding of subject material. I also believe that innovative assessment techniques aligned to PBL can engage students in learning that lasts beyond college. This is evident through findings where many students considered their mathematical competence could now be used as 'another skill' they could develop further in the work place. From reflective diaries used throughout the research process and through engagement with PBL, I have also found my own professional practice and personal development has improved and become more enjoyable over the course of the study. Research results were very positive throughout, with most participants reporting levels of understanding and enjoyment of learning not previously experienced with this subject.

However, this small-scale study was carried out using just one subject from a very large curriculum wherein rote learning is seen to be extensive. It was beyond the control of this project to change any of the summative assessments, but it was a change from the constraints of this curriculum and to test student-centred learning that inspired much of the research. With very few exceptions, the students who participated in this study agreed that they found the PBL method of learning and teaching more productive to their learning needs, more engaging through challenging real-life design work, and more resourceful in providing them with the competencies they need to work within their chosen craft discipline. What is generally agreed throughout the research literature is that modern society requires a fundamentally different conceptual discourse for assessment (Clegg & Bryan, 2006). Such assessment activities should not only address the immediate needs of certification to students on their current learning, but also contribute in some way to their prospective learning (Boud & Falchikov, 2006).

6.3 Recommendations

These recommendations were compiled from findings collated throughout the research study period together with a reflective analysis of the main objectives of the research, as summarised in Section 6.1 and detailed in Section 1.4. The recommendations that emerge from this action research study are as follows.

6.3.1 Phase Six Apprenticeship Learning and Understanding

The research findings along with many discussions with participating students, to a comprehensive analysis of the curriculum and my own teaching experience, all indicate that the current plumbing phase six curriculum is congested and leading to didactical teaching methods and rote learning. The summative assessments associated with this curriculum and discussed above tend to exacerbate the problem. As much as possible, the workload expected of students should be realistic, and the assessment system should be non-threatening and non-anxiety provoking (Rust, 2002).

Society now demands more than passive graduates who have complied with a rigid regime, and employers and professional groups are placing expectations on institutions to deliver graduates who are prepared for and can cope with the real world of work (Boud, 2006). Student-centred learning can foster knowledgeable, competent, reflective and committed learners (Mentkowski, 2006), that are more prepared for the unorthodox type of real work problems that are associated with craft disciplines. This paradigm change may not necessarily mean an alternative model of apprenticeship, but an alternative and more innovative form of assessment of learning and understanding. This I believe could enhance the ‘standards based’ element of the off-the-job phases of apprenticeship by increasing understanding and enabling learners to adapt to changing situations.

The craft of plumbing while having a comprehensive list of common core subjects, then traditionally diversifies to encompass apprenticeship training coming predominantly from either industrial or domestic backgrounds. Most of the apprentices reaching the off-the-job phase six of their training have gained most of their knowledge and skills from their own particular craft background. However, they are then placed together within a curriculum that includes specialist areas from either end of the domestic and industrial spectrum along with a host of common core subjects including applied calculations and mathematics. If many of these specialist type subjects (listed below) were to be removed from such an exhaustive curriculum, (elaborated upon in section 1.3.1), then maybe the core craft subjects, that many students have expressed concern with not fully understanding, could be more comprehensively taught and assessed using a form of student-centred learning such as PBL. These specialist subjects could then be later offered as ‘add-on’ subjects to suit the individual craftsperson or his/her companies’ particular needs.

An example of some of these subjects, taken from Tables 2 & 3 of Section 1.3.1, are typical of areas that are predominately related to either the domestic or industrial craft discipline. Whilst basic information about these subjects could be disseminated to students, the choice for in-depth knowledge and specialism might be a career or company choice. The modules listed below are an example of such subjects.

- Module 4: Unit Numbers 1, 2, 3, 4, 5, & 6: Gas Installation Safety

This complete module has its own summative T1 assessment for those wishing to progress to domestic gas installation work. Whilst this module suits domestic oriented apprentices, many industrial apprentices have no experience of domestic gas installations. This module with an allocated lecture time of 44 hours might be better suited as a separate specialist course for those working within this area.

- Module 1: Unit Numbers 1, 2, 3, 4, & 5: Thermal Processes and Pipefitting

Within this module there are three practical assessments in Tig, Arc and Gas welding, all of which are related to industrial plumbing installations. Whilst this module suits industrial oriented apprentices, many domestic apprentices have not practiced these skills since completing phase two or four of their training. This module with an allocated training time of 135 hours might also be better suited as a separate specialist course for those working within this area.

There are other examples of subjects within the curriculum such as, domestic heating control wiring, and industrial steam systems, at either end of the spectrum, which individual companies specialising within these areas could provide ‘add-on’ training for individual craftspeople. From the cycle two focus group, participant E summed up the general feelings of the group; *“I have worked in industrial plumbing for the past six years, there are electricians on site and we are not allowed to touch any wiring, now there could be a chance of me being referred in domestic control wiring which I have never done or am ever likely to do.”* Participant A, retorted; *“these could be separate courses that we can choose to go on after here (phase six)”*.

Leaving the core subjects applicable to both industrial and domestic craft areas that the majority of student apprentices feel they need to understand more, would I believe, better equip students to acknowledge from this foundational understanding, which additional specialist areas they may need to pursue in the future. From the findings presented in Chapters Four and Five, using the subject of applied calculations, I consider it safe to suggest that the extended use of PBL to include all of the common core plumbing subjects into one continually assessed design project might provide for the learning with understanding advocated throughout modern educational research literature as discussed in Sections 3.2 and 6.2. From the findings presented in Chapters Four and Five, I also believe that learning the common core subjects through PBL may foster a deeper understanding of these topics, and provide students with an increased confidence in their ability to learn within new areas.

With PBL, students can present what they know or what they can do within a project design and be continually assessed on their understanding of each subject. Assessment can then become an integral part of teaching rather than a separate activity occurring after teaching (Holroyd, 2000). This would also mean that subject matter is being continually decreased and incorporated into the students learning during the course, rather than an accumulation of more than thirty subjects from which to be questioned from at the end of term.

6.3.2 The Maths Problem

In Section 2.2.1, much of the research literature indicates that mathematics education in Irish second level education is strongly didactic, driven by state examinations where students rely on rote memory as an alternative to understanding (Engineers-Ireland, 2010). Further research literature reviewed in Section 2.2.1 reveals that there also appears to be an International problem with second level mathematical education (Engineers-Ireland, 2010; Hourigan & O'Donoghue, 2007; NCCA, 2005). The above literature indicates that much is lacking in second level mathematical education from where the majority of student apprentices come.

As discussed in Chapters Four and Five, this research project has also found mathematical knowledge to be lacking in many phase six student apprentices from which the majority hold a Leaving Certificate. Also discussed in the above chapters is how, through the introduction of PBL, students understanding, confidence and ability to use craft applied calculations and mathematics improved over each research cycle.

This research suggests that if a form of student-centred learning such as PBL were introduced within second level education then improvements in mathematical understanding could also be made there. Moreover, recent literature (Engineers-Ireland, 2010; NCCA, 2005) have recommended the use of problem and project-based learning within Irish second level education. Engineers-Ireland (2010) also support the ‘Project Maths’ initiative, as discussed in Section 1.2, which places an emphasis on understanding and interpretation of problems rather than rote learning. Also as recent as April 2010 the Irish Minister for Education, Ms. Mary Coughlan, launched a consultation process on the reform of the junior cycle in second level schools (DoE&S, 2010). This consultation is being undertaken by the NCCA in the light of best international practice to advise on the most appropriate nature and form of assessment.

> Our learners need to be flexible, adaptable, resilient and competent if they are to participate successfully in society and be enabled as independent learners throughout the whole of their lives. They need to develop critical thinking skills and move away from rote learning. Curriculum reform must result in a more active learning experience for the individual, promote a real understanding within learning and aim to embed a seed of creativity and innovation in the learner. This will also better equip students for the demands of the senior cycle (DoE&S, 2010).

With all of the above research literature and Government comments advocating a move from traditional teaching and assessment methods, to student-centred, learning through understanding approaches, I would argue that this should also be incorporated into apprenticeship education and training. I also believe that the introduction of PBL into second level education, where students are encouraged to engage in a level of self-assessment might contribute to a more seamless transition to further education and beyond.

6.3.3 Current Assessment Methods

This section was included to show a comparison of the type of continuous and self-assessment recommended in modern educational literature and also discussed in Section 6.2, and the current phase six apprenticeship model. The section was also included to offer suggestions for improvements based on recommendations made in Section 6.3.2 above. The current phase six plumbing time constrained theoretical summative assessments have been discussed throughout this research project. The marking procedures for these assessments however, have not been elaborated upon.

Lecturers who have taught these students for the course duration (usually eleven weeks) correct their phase six theoretical examinations, and all but one of their practical assessments (P 2), which is marked by an external company using a non-destructive x-ray process. The theoretical examinations are marked by a single lecturer for each group of apprentices and are not marked anonymously. There is no second marker, and there is also no external examiner. There is also no quality control representative or scrutiny provided from the curriculum provider – FÁS (Field & O'Dubhchair, 2001), even when referral rates seem unusually high. Judgment by those who have been teaching the students are generally regarded as less robust and dependable than examinations marked by individuals who are not at all involved in teaching the individual students (Murphy, 2006). Feedback for referred students as to where they may have gone wrong is also not available as they are back in employment by the time they receive their results. This operates contrary to the continuous assessment and immediate formative feedback available through the use of PBL. There is a €25.00 fee for rechecking referred exam scripts but this does not include any feedback. If examination scripts are remarked in favour of a ‘pass’ the student is reimbursed the cost of the recheck. As discussed in Section 2.2.3, that while the primary source of uncertainty in the quality of apprenticeship assessments lies in the reliability (and even existence) of the on-the-job assessments, there is also potential risks to the credibility of the off-the-job elements (Field & O'Dubhchair, 2001).

Therefore, it could be suggested that summative examination scripts for as long as they continue to exist could be exchanged for ‘blind’ marking between compatible institutions, with an external examiner appointed to each centre. The implementation of PBL in place of these summative examinations would also enable students to present their learning achievements to many lecturers for grading over the duration of their course. Students may escape from poor teaching through their own activities, but they are trapped by the consequences of poor assessment, as it is something they are required to endure if they want to graduate (Boud, 2006).

6.3.4 Extended Use of PBL

The timeframe for this action research project did not allow for the inclusion of a web-based integration. However, I believe that much could be done in this area to enhance the use of PBL even further than was possible here. Many of the projects that were disseminated in class could also be incorporated into a web-based programme with immediate formative feedback and assessments built in. This facility could also enable students to develop an e-portfolio of their learning achievements. Applied calculations and mathematics revision packages applicable to particular crafts could also be integrated within a web-based design similar to the D.I.T Student Maths Learning Centre (D.I.T.SMLC, 2010). A range of student supports for those new to PBL and to help students learn how to learn could also be incorporated.

The world of construction relies heavily on people being able to work closely in teams where planning and co-ordination is of high importance. The ability to communicate effectively and work cooperatively with others within a fast paced environment, are just some of the essential skills required from all participants in the construction process. Therefore, it could also be recommended that in the long term, projects used within PBL could be shared electronically, among various crafts to foster such communication and co-ordination type skills. It is worth remembering that most projects take time to develop and usually evolve over several years (PBLE-Guide, 2003).

6.3.5 Continuing Professional Development (CPD)

Discussed in Section 6.1, was the paradigm shift in education from a focus on teaching to a focus on learning. In order to keep up to date with such modern literature and recommendations from professional bodies and government sources, I believe it is important that those involved in education to continually update their knowledge and skills. This professional development may extend to include such topics as, innovative assessment techniques, constructive alignment, project and problem-based learning, webcourses, and modern electronic teaching aids such as ‘clickers’, ‘smartboards’, and ‘txttools’ etc. I also believe it is important to engage in continual research within one’s own professional expertise in order to provide students with knowledge of the most current techniques and technology being used in today’s industries.

Action research, whilst being used for personal professional development (Elliott, 1991), can also be used to make recommendations for curriculum, environmental or institutional changes and improvements. Action research has always been understood as people taking action to improve their personal and social situations (McNiff & Whitehead, 2006).

6.4 Chapter Summary

This chapter set out to offer conclusions and recommendations from an action research study carried out over a ten-month period and reported upon within this thesis. The ongoing paradigm shift from a focus on teaching to one of learning was also highlighted along with the importance of assessment within this changing environment. The chapter also emphasised how a constructively aligned curriculum using continuous assessment techniques and feedback may help foster a deeper approach to learning. A comparative analysis of two course characteristics provided recommendations of approaches that can cultivate such an approach. The benefits of self-assessment and peer learning aligned within these course characteristics was also highlighted in Section 6.2.

Among the recommendations made within this chapter was the refinement of the phase six plumbing curriculum and assessment criteria to reflect modern educational research literature, and professional institutions suggestions to incorporate systems of student-centred learning. Other recommendations included the incorporation of forms of student-centred learning within the second level educational system in line with the 'project-maths' initiative, and an extension of this type of initiative within the current apprenticeship system. Recommendations regarding the extended use of PBL to incorporate web-based project material and continuing professional development in such areas as electronic teaching aids was also discussed.

6.5 Reflections

The primary aim of this action research study was to establish, if a deeper understanding and application of building services applied mathematics could be achieved through the implementation of project-based learning within apprenticeship education. Sections 5.6, 5.7, and 5.8 go some way in detailing how this aim was achieved. The motivation for the research lay in my commitment for further personal development and improvement within my own practice.

I enjoyed my research immensely and found the experience most worthwhile. I can honestly say that my research has made me more understanding of the problems that many students have with applied calculations and mathematics in general. I can also better appreciate the dilemma in which many students find themselves, when being exposed to a curriculum that promotes surface and rote learning over the type of understanding wished for, by the majority of apprentices who took part in the research. My own commitment to the study was helped by the practical relevance of the research to my own practice and also to that of the craft subject. The continued high motivational levels of the participant students engaged in the research projects further inspired my commitment to it. I have also found throughout this research that there is a definite advantage of being an, 'inside' researcher. For example, I had a thorough knowledge of the context of the research, participants were easily reached and interviews were easily arranged.

However, at times it was difficult because I was engaged in both research and action change, along with other teaching commitments, where each would have been enough over the given time frame. But I am committed to teaching and the action was very important in an effort to make improvements the educational experience of phase six student apprentices. The more we can engage students in assessment activities that are meaningful to them and which contribute to their learning, the more satisfying will be their educational experience (Boud, 2006).

This qualitative action research study was also based on the premise that research in schools and colleges and in other educational settings can lead to change and improvement. At the very least this action research project has had an impact on the professional development of the author. But it may also encourage small changes in practice, such a development of a policy. It may even underpin a major change in the ethos that affects apprenticeship education. However, whatever the findings of the research, in many cases, the researcher is unlikely to have the power or authority to implement changes or have the final say on policy (Browne & Jones, 2001). Nevertheless, if other action research projects developed from similar concerns combine to present common findings; then maybe educational changes and improvements may be seen as a valid requirement.

6.6 Concluding Remarks

The introduction of a new learning and teaching pedagogy such as PBL within plumbing apprenticeship was challenging to plan and enact. To also produce a qualitative action research thesis on its implementation over a short ten-month period was even more demanding. However, even though PBL presents many more challenges for the teacher and students, I believe the learning rewards for both far outweigh any extra effort involved.

I have found this action research project to evolve and improve over the research period, and as discussed earlier, it is not my intention to stop upon completion of this study. Instead this research may be extended to incorporate other subjects and also a web-based integration. I have found Project-Based Learning a most worthwhile platform from which to develop and promote learning through understanding to apprentice craftspeople. It is with one of these student participants that I leave the final remark.

"I remember every project that I have ever done, I sat an exam last Friday and I can't remember what was in it." (Apprentice from cycle two remarking on PBL and the T2 plumbing summative assessment)

References

1977-Report. Report of the working party on school mathematics in relation to craft and technician apprenticeships in the engineering industry. *International Journal of Mathematical Education in Science and Technology, 8*(4), 485-493.

AARE. (2010). Australian Association for Research in Education - Code of Ethics Retrieved 9th January 2010, from http://www.aare.edu.au/ethics/ethcfull.htm

Ackerman, E. (2010). Piaget's Constructivism, Papert's Constructionism: Whats the difference.   Retrieved 27th February 2010, from http://learning.media.mit.edu/content/publications/EA.Piaget%20_%20Papert.pdf

Action Research Resources. (2009).   Retrieved 29th November 2009, from http://www.scu.edu.au/schools/gcm/ar/arhome.html

AERA. (2009). *Standards for Reporting on Humanities-Oriented Research in AERA Publications*.

Allison, P., & Pomeroy, E. (2000). How Shall We "Know"? Epistemological Concerns in Research in Experiential Education. *The Journal of Experiential Education, 23*(2), 91-98.

Altrichter, H., Kemmis, S., McTaggart, R., & Zuber-Skerritt, O. (2002). The concept of action research. *The Learning Organisation, 9*(3), 125-131.

Andrié, M. (1985). Application-orientated mathematics in the education of engineers. *International Journal of Mathematical Education in Science and Technology, 16*(2), 157-162.

Angelides, P. (2001). The development of an efficient technique for collecting and analyzing qualitative data: the analysis of critical incidents *International Journal of Qualitative Studies in Education, 14*(3), 429-442.

Armstrong, D. G., & Kleiner, B. H. (1996). Transferring learning to the workplace. *Managemnt Development Review, 9*(1), 8-12.

Artemiadis, N. K. (2009). Educational Systems (ES) in Mathematics and other related topics. *Journal of Computational and Applied Mathematics, 227*, 5-9.

Avramidis, E., & Smith, B. (1999). An Introduction to the Major Research Paradigms and their Methodological Implications for Special Needs Research. *Emotional and Behavioural Difficulties, 4*(3), 27-36.

Baldock, T. E., & Chanson, H. (2006). Undergraduate teaching of ideal and real fluid flows: the value of real-world experimental projects. *European Journal of Engineering Education, 31*(6), 729-739.

Barron, B. J. S., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., et al. (1998). Doing with Understanding: Lessons from Research on Problem and Projrct-Based Learning. *The Journal of the Learning Sciences, 7*(3/4 Learning through Problem Solving), 271-311.

Basit, T. N. (2003). Manual or Electronic? The role of coding in qualitative data analysis. *Educational Research, 45*(2), 143-154.

Beck, V., Fuller, A., & Unwin, L. (2006). Increasing risk in the 'scary' world of work? Male and female resistance to crossing gender lines in apprenticeships in England and Wales. *Journal of Education and Work, 19*(3), 271-289.

Bell, J. (2005). *Doing your Research Project: A guide to first-time researchers in education, health and social science* (4 ed.). Berkshire: Open University Press.

BERA. (2004). Revised Ethical Guidelines for Educational Research (2004). Retrieved 9th January 2010, from http://www.bera.ac.uk/files/guidelines/ethica1.pdf

Bergh, V. V. d., Mortelmans, D., Spooren, P., Petegem, P. V., Gijbels, D., & Vanthournout, G. (2006). New Assessment Modes Within Project-Based Education - The Stakeholders. *Studies in Educational Evaluation, 32*, 345-368.

Berry, R. S. Y. (1999). *Collecting data by in-dept interviewing*. Paper presented at the British Educational Research Association Annual Conference.

Biggs, J. (2003). *Teaching for Quality Learning at University* (2 ed.). Berkshire: Open University Press.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating Project Based Learning: Sustaining the Doing, Supporting the Learning. *Educational Psychologist, 26*(3 & 4), 369-398.

Boeije, H. (2010). *Analysis in Qualitative Research*. London: SAGE Publications.

Boud, D. (2000). Sustainable Assessment: rethinking assessment for the learning society. *Studies in Continuing Education, 22*(2), 151-167.

Boud, D. (2006). Foreword. In C. Bryan & K. Clegg (Eds.), *Inovative Assessment in Higher Education* (pp. xvii-xix). London: Routledge.

Boud, D., Cohen, R., & Sampson, J. (1999). Peer Learning and Assessment. *Assessment & Evaluation in Higher Education, 24*(4), 413-426.

Boud, D., & Falchikov, N. (2006). Aligning assessment with long-term learning. *Assessment & Evaluation in Higher Education, 31*(4), 399-413.

Boyne, R. (2006). Subjectivity. In V. Jupp (Ed.), *The SAGE Dictionary of Social Research Methods* (pp. 293-294). London: SAGE Publications.

Breen, S., Cleary, J., & O'Shea, A. (2009). An investigation of the matematical literacy of first year third-level students in the Republic of Ireland. *International Journal of Mathematical Education in Science and Technology, 40*(2), 229-246.

Bridges, D. (2003). A Philosopher in the Classroom. *Educational Action Research, 11*(2), 181-196.

Brooker, R., & Butler, J. (1997). The learning context within the workplace: as perceived by apprentices and their workplace trainers. *Journal of Vocational Education and Training, 49*(4), 487-510.

Browne, T., & Jones, L. (2001). *Action Research and Postmodernism: congruence and critique*. Buckingham: Open University Press.

Bryan, C., & Clegg, K. (2006). Introduction. In C. Bryan & K. Clegg (Eds.), *Innovative Assessment in Higher Education* (pp. 1-7). London: Routledge.

Butler, J., & Brooker, R. (1998). The learning context within technical and further education colleges: as perceived by apprentices and their workplace supervisors. *Journal of Vocational Education and Training, 50*(1), 79-96.

Carr, W., & Kemmis, S. (1986). *Becoming Critical: Education, Knowledge and Action Research*. London: The Falmer Press.

Carroll, C. (2005). Assessing Project-Based Learning: A case Study of an Undergraduate Selling and Sales Management Module at the University of Limerick. *Handbook of Enquiry & Problem based Learning*, 95-102.

CEDEFOP. (2009). European Centre for the Development of Vocational Training. Retrieved 14th December 2009, from http://www2.trainingvillage.gr/etv/library/apprenticeship/country/irl.asp

Christou, P. E., Valachis, I., & Anastasiadou, D. C. (2009). Research Methodology in Hospitality Industry: The role of the Inquiry Paradigms. Retrieved 21st February 2010, from http://www.ul.edu.lb/fthm/papers/3rd%20Axis/Methodology%20greece.doc

CIPHE. (2009a). Chartered Institute of Plumbing and Heating Engineering. *Careers* Retrieved 28th October 2009, from http://www.ciphe.org.uk/Professional/Careers/

CIPHE. (2009b). The Chartered Institute of Plumbing and Heating Engineering. *Training Guidelines* Retrieved 29th October 2009, from http://www.ciphe.org.uk/Global/PDF%20files/Training%20Guidlines%20FAQ.pdf

CIPHE-SummitSkills. (2007). Minimum Technical Competency of Individuals undertaking Plumbing Installation work, *Pb MTC Version 1: 01/07/2007*.

Clarke, L., & Winch, C. (2006). A European skills framework? - but what are skills? Anglo-Saxon versus German concepts. *Journal of Education and Work, 19*(3), 225-269.

Clegg, K., & Bryan, C. (2006). Reflections, rationales and realities. In C. Bryan & K. Clegg (Eds.), *Innovative Assessment in Higher Education* (pp. 216-227). London: Routledge.

Cohen, L., Manion, L., & Morrison, K. (2000). *Research Methods in Education* (5 ed.). London: Routledge Falmer.

Colley, H., James, D., Tedder, M., & Diment, K. (2003). Learning as becoming in vocational education and training: class, gender and the role of vocational habitus. *Journal of Vocational Education and Training, 55*(4), 471-498.

Collins, A., Brown, J. S., & Newman, S. E. (1987). *Cognitive Apprenticeship: Teaching the Craft of Reading, Writing and Mathematics* (No. 403): University of Illinois.

Collins, A., Browne, J. S., & Newman, S. (1989). Cognitive Apprenticeship: Teaching the Crafts of reading, writing and mathematics. Retrieved 15th November 2009, from http://mathforum.org/~sarah/Discussion.Sessions/Collins.html

Collins, S. (2004). Ecology and Ethics in Participatory Collaborative Action Research: an argument for the authentic participation of students in educational research. *Educational Action Research, 12*(3), 347-362.

Conway, S. (2007). Apprenticeship Follow-up Survey: The views and experiences of 1999 registrants. *FAS Planning and Research*, 1-39.

Creswell, J. W. (1998). *Qualitative Enquiry and Research Design: Choosing Among Five Traditions*. London: SAGE Publications Ltd.

Crotty, M. (1998). *The Foundations of Social Research: Meaning and Perspective in the Research Process*. London: SAGE Publications.

Crowther, K., Thompson, D., & Cullingford, C. (1997). Engineering degree students are deficient in mathematical expertise - why? *International Journal of Mathematical Education in Science and Technology, 28*(6), 785-792.

D.I.T. (2009). DT151 Advanced Plumbing & Mechanical Services Course http://www.dit.ie/study/parttime/programmes/dt151advancedplumbingmechanicalservices/. Retrieved 22nd November 2009

D.I.T. (2010a). Examination Secretaries' Report. Linen Hall: Dublin Institute of Technology.

D.I.T. (2010b). Guidelines for Undergraduates and Taught Postgraduates. Retrieved 9th January 2010, from http://www.dit.ie/researchandenterprise/research/researchsupportoffice/ethics/guidelines/guidelinesfortaughtstudents/

D.I.T. (2010c). Guiding Principals. Retrieved 9th January 2010, from http://www.dit.ie/researchandenterprise/research/researchsupportoffice/ethics/guidelines/

D.I.T.SMLC. (2010). Students Maths Learning Centre. Retrieved 05th June 2010, from http://www.maths.dit.ie/mlc/html/crash_courses.html

Denscombe, M. (1998). *The Good Research Guide for Small-scale Social Research Projects*. Buckingham: Open University Press.

Denzin, N. K., & Lincoln, Y. S. (2005). Introduction: The Discipline and Practice of Qualitative Research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research* (3 ed., pp. 1-32). London: SAGE Publications.

Dick, B. (2002). postgraduate programs using action research. *The Learning Organisation, 9*(4), 159-170.

Dickson, L. (1979). A case study based on the mathematical achievements and experiences of ten London Transport craft apprentices. *International Journal of Mathematical Education in Science and Technology, 10*(2), 251-278.

DoE&S. (2010). Tánaiste launches consultation process on reform of junior cycle. Retrieved 04th June 2010, from http://www.education.ie/home/home.jsp?maincat=&pcategory=10861&ecategory=10876&sectionpage=12251&language=EN&link=link001&page=1&doc=49023

Draper, A. K. (2004). The principals and application of qualitative research. *Proceedings of the Nutrition Society, 63*, 641-646.

Earl-Slater, A. (2002). The Superiority of Action Research. *British Journal of Clinical Governance, 7*(2), 132-135.

Education-Commission. (2000). Education Reform.   Retrieved 27th November 2009, from http://www.e-c.edu.hk/eng/reform/index_e.html

Elliott, J. (1991). *Action Research for Educational Change*. Buckingham: Open University Press.

Engineers-Ireland. (2010). *Report of Task Force on Education of Mathematics and Science at Second Level*.

English, J., O'Donoghue, J., & Bajpai, A. C. (1992). What Irish Pupils say about mathematics. *International Journal of Mathematical Education in Science and Technology, 23*(5), 749-763.

Ertl, H. (2006). European Union policies in education and training: the Lisbon agenda as a turning point? *Comparative Education, 42*(1), 5-27.

ESF. (1999). *European Social Fund Evaluation Unit Evaluation Report: Apprenticeship and Traineeship*. Dublin.

ESF-Ireland. (2007-2013). The European Social Fund in Ireland 2007 - 2013. Retrieved 15th December 2009, from http://www.esf.ie/en/homepage.aspx

ESRC. (2010). Framework for Research Ethics 2010.   Retrieved 30th March, 2010, from http://www.esrcsocietytoday.ac.uk/ESRCInfoCentre/Images/Framework%20for%20Research%20Ethics%202010_tcm6-35811.pdf

Eurofound. (2009). Programme for Economic ans Social Progress.   Retrieved 14th December 2009, from http://www.eurofound.europa.eu/emire/IRELAND/PROGRAMMEFORECONOMICANDSOCIALPROGRESS-IR.htm

Fairtlough, A. C. (2007). Adapting the voice-centred relational method of data analysis: reading trainees' accounts of their learning on a pilot programme for practitioners working with parents. *Journal Compilation, 6*(1), 2-13.

FÁS. (2006a). Plumbing Curriculum, *Introduction to Phases 2, 4 & 6 Off-the-job* (pp. 1-19). Dublin: Curriculum and Quality Assurance Department FAS - Training and Employment Authority.

FÁS. (2006b). Plumbing Curriculum General Introduction to the Apprenticeship Programme: Revision 2.2, *Apprenticeship Training Programmes* (pp. 1-16). Dublin: Curriculum and Quality Assurance Department - FÁS.

FÁS. (2009a). Apprenticeship Training Eligibility and Assessment. Retrieved 15th December 2009, from http://www.fas.ie/en/Training/Apprenticeships/Eligibility+and++Assessment.htm

FÁS. (2009b). Apprenticeships. Retrieved 10th October 2009, from http://www.fas.ie/en/Training/Apprenticeships/default.htm

FÁS. (2009c). Curriculum. Retrieved 15th October 2009, from http://www.fas.ie/en/Training/Apprenticeships/Curriculum.htm

FÁS. (2010). Training: Apprenticeship Listings. Retrieved 9th February 2010, from http://www.fas.ie/en/Training/Apprenticeships/Apprenticeship+Listings/default.htm

Field, J., & O'Dubhchair, M. (2001). Recreating Apprenticeship: lessons from the Irish standards-based model. *Journal of Vocational Education and Training, 53*(2), 247-261.

Fischer, G., & Scharff, E. (1998). Learning Technologies in Support of Self-Directed Learning. *Journal of Interactive Media in Education, 98*(4), 1-32.

Fitzpatrick, J. (2006). Self-assessment as a strategy to provoke integrative learning within a professional degree programme. *Learning in Health and Social Care, 5*(1), 23-34.

Flynn, S. (2009, November 3rd). Final Junior Cert exam likely to be in June 2012. *The Irish Times,* p. 6.

Fuller, A., & Unwin, L. (1998). Reconceptualising apprenticeship: exploring the relationship between work and learning. *Journal of Vocational Education and Training, 50*(2), 153-173.

Fuller, A., & Unwin, L. (2007). What counts as good practice in contempoary apprenticeships? *Education and Training, 49*(6), 447-458.

Gavalas, D. (2001). Study of the 'teaching system' according to systems theory. *International Journal of Mathematical Education in Science and Technology, 31*(2), 261-268.

Gibbs, G. (1992). *Improving the Quality of Student Learning*. Bristol: Technical and Educational Services

Gibbs, G. (2006a). How assessment Frames Student Learning. In C. Bryan & K. Clegg (Eds.), *Innovative Assessment in Higher Education* (pp. 23-36). London: Routledge.

Gibbs, G. (2006b). Why Assessment is Changing. In C. Bryan & K. Clegg (Eds.), *Innovative Assessment in Higher Education* (pp. 11-22). London: Routledge.

Gibbs, G. (2007). *Analysing Qualitative Data*. London: SAGE Publications.

Gibbs, P., Costley, C., Armsby, P., & Trakakis, A. (2007). Developing the ethics of worker-researchers through phronesis. *Teaching in Higher Education, 12*(3), 365-375.

Gibson, I. S. (2003). From solo-run to mainstream thinking: project-based learning in enginering design. *European journal of Engineering Education*, *28*(3), 331-337.

Gibson, I. S., O'Reilly, C., & Hughes, M. (2002). Integration of ICT within a project-based learning environment. *European journal of Engineering Education, 27*(1), 21-30.

Goggin, B. (2004). *Apprenticeship as a Paradigm of Learning*. Cork: Institute of Technology Apprentice Commission.

Grant, M. M. (2002). Getting a grip on project based learning: Theory, cases and recommendations *Meridian: A Middle School Computer Technologies Journal*, *5*(1).

Grbich, C. (2007). *Qualitative data analysis: An Introduction*. London: SAGE Publications.

Green, J. A., Azevedo, R., & Torney-Purta, J. (2008). Modeling Epistemic and Ontological Cognition: Philosophical Perspectives and Methodological Directions. *Educational Psychologist, 43*(3), 142-160.

Greenwood, D. J., & Levin, M. (2005). Reform of the Social Sciences and of Universities through Action Research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research* (3 ed., pp. 43-64). London: SAGE Publications.

Grimson, J. (2002). Re-engineering the curriculum for the 21st century. *European Journal of Engineering Education*, *27*(1), 31-37.

Grix, J. (2002). Introducing Students to the Generic Terminology of Social Research. *Politics*, *22*(3), 175-186.

Grugnetti, L., & Jaquet, F. (2005). A mathematical competition as a problem solving and a mathematical education experience. *Journal of Mathematical Behavior, 24*, 373-384.

Guba, E. G., & Lincoln, Y. S. (2005). Paradigmatic Controversies, Contradictions, and Emerging Confluences. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research* (3 ed., pp. 191-215). London: SAGE Publications.

Guile, D., & Okumoto, K. (2007). We are trying to reproduce a crafts apprenticeship: from Government Blueprint to workplace-generated apprenticeship in the knowledge economy. *Journal of Vocational Education and Training, 59*(4), 551-574.

Haghighi, A. M., Vakil, R., & Wetiba, J. K. (2006). Reverse-Traditional / Hands-on: An Alternative Method of Teaching Statistics. *Application and Applied Mahtematics, 1*(1), 62-82.

Harris, R., & Simons, M. (2005). Exploring the notion of retention in apprenticeship. *Education and Training, 47*(4/5), 350-365.

Harris, R., Willis, P., Simons, M., & Collins, E. (2001). The relative contributions of institutional and workplace learning environments: an analysis of apprenticeship training. *Journal of Vocational Education and Training, 53*(2), 263-278.

Hart, C. (2005). *Doing your Masters Dissertation*. London: SAGE Publications Ltd.

HEA. (2009). The Higher Education Academy: Fund for the Development of Teaching and Learning (FDTL). Retrieved 27th November 2009, from http://www.heacademy.ac.uk/ourwork/supportingresearch/fdtls

HEA-Forfás. (2007). *The Role of the Institutes of Technology in Enterprise Development: Profiles and Emerging Findings*.

Heitmann, G. (1996). Project-oriented Study and Project-organised Curricula. *European journal of Engineering Education, 21*(2), 121-131.

Helle, L., Tynjala, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education - theory, practice and rubber sling shots. *Higher Education, 51*, 287-314.

Hepburn, A. (2006). Constructionism. In V. Jupp (Ed.), *The SAGE Dictionary of Social Research Methods* (pp. 38-40). London: SAGE Publications.

Heraty, N., Morley, M. J., & McCarthy, A. (2000). Vocational Educational and Training in the Republic of Ireland: Institutional reform and policy developments since the 1960s. *Journal of Vocational Education and Training, 52*(2), 177-199.

Higher Education Authority. (2009). Retrieved 05th December 2009, from http://www.hea.ie/en/node/1317

Hillon, M. E., & Boje, D. M. (2007). The social ecology of action research. *Management Research News, 30*(5), 359-367.

Hinch, P. (2007). Can blending face-to-face teaching with e-learning support the development of apprentices in mathematics. *Scottish Online Journal of e-Learning, 1*(1), 2-14.

Hirst, C., Williamson, S., & Bishop, P. (2004). A holistic approach to mathematics support for engineering. In C. Gaille & I. Moore (Eds.), *Effective Learning and Teaching in Engineering* (pp. 100-121). Oxon: Routledge Falmer.

Holroyd, C. (2000). Are assessors professional?: Student assessment and the professionalism of academics. *Active Learning in Higher Education, 1*(1), 28-44.

Hourigan, M., & O'Donoghue, J. (2007). Mathematical under-preparedness: the influence of the pre-tertiary mathematics experience on students' ability to make a successful transition to tertiary level mathematics courses in Ireland. *International Journal of Mathematical Education in Science and Technology, 38*(4), 461-476.

Howe, K. R., & Moses, M. S. (1999). Ethics in Educational Research. *Review of Research in Education, 24*, 21-60.

Huddelston, P. (1998). Modern apprentices in college: "something old, something new". *Journal of Vocational Education and Training, 50*(2), 277-290.

Hung, D. W. L. (2000). Some insights into the generalizing of mathematical meanings. *Journal of Mathematical Behavior, 19*, 63-82.

Irishtimes.com. (2009). Final Junior Cert exam likely to be in June 2012. Retrieved 5th November 2009, from http://www.irishtimes.com/newspaper/ireland/2009/1103/1224257963841.html

James, P., & Mulcahy, D. (2000). Competency-based training and beyond: action research and reflective practice in vocational education and training. *Educational Action Research, 8*(3), 515-532.

Johnson, S. D., & Fischbach, R. M. (1992). *Teaching Problem Solving and Technical Mathematics* (Reports - Research/Technical (143)): National Centre for Research in Vocational Education: Berkley, CA.

Jones, M., & Stanley, G. (2008). Childrens lost voices: ethical issues in relation to undertaking collaborative, practice-based projects involving schools and the wider community. *Educational Action Research, 16*(1), 31-41.

Kamberelis, G., & Dimitriadis, G. (2005). Focus Groups: Strategic Articulations of Pedagogy, Politics, and Inquiry. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research* (3 ed., pp. 887-907). London: SAGE Publications.

Kellaghan, T., Morgan, M., Fitzpatrick, M., & Millar, D. (2002). An Evaluation of the Sole Use of Short-Answer Tests in Apprenticeship Examinations. *Education Research Centre, Dublin, 1*(1), 1-73.

Kemmis, S. (2009). Action research as a practice-based practice. *Educational Action Research, 17*(3), 463-474.

Kemmis, S., & McTaggart, R. (2005). Participatory Action Research: Communicative Action and the Public Sphere. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research* (3 ed., pp. 559-604). London: SAGE Publications.

Keppell, M., Eliza Au, Ada, & Chan, C. (2006). Peer learning and learning-oriented assessment in technology-enhanced environments. *Assessment and Evaluation in Higher Education, 31*(4), 453-464.

Khanlou, N., & Peter, E. (2005). Participatory action research: considerations for ethical review. *Social Science & Medical, 60*, 2333-2340.

Kincheloe, J. L., & McLaren, P. (2005). Rethinking Critical Theory and Qualitative Research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research* (3 ed., pp. 303-342). London: SAGE Publications.

Klymchuk, S., Zverkova, T., Gruenwald, N., & Sauerbier, G. (2008). Increasing engineering students' awareness to environment through innovative teaching of mathematical modelling. *Teaching Mathematics and it's Applications, 27*(3), 123-130.

Knight, A., & Turnbull, N. (2008). Epistemology. In A. Knight & L. Ruddock (Eds.), *Advanced Research Methods in the Built Environment* (pp. 64-74). Oxford: Wiley-Blackwell.

Kolb, D. A. (1984). *Experimental Learning*. Englewood Cliffs, NJ: Prentice Hall.

Kolmos, A. (1996). Reflections on Project Work and Problem-based Learning. *European Journal of Engineering Education, 21*(2), 141-148.

Koro-Ljungberg, M., Yendol-Hoppey, D., Smith, J. j., & Hayes, S. B. (2009). Epistemological Awareness, Instantiation of Methods, and Uniformed Methodological Ambiguity in Qualitative Research Projects. *Educational Researcher, 38*(9), 687-699.

Krauss, S. E. (2005). Research Paradigms and Meaning making: A Primer. *The Qualitative Report, 10*(4), 758-770.

Krueger, R. A. (1998). *Analyzing and Reporting Focus Group Results* (Vol. 6). London: SAGE Publications Ltd.

Lawrence, D. J. (2006). The Ethics of Educational Research. *Journal of Manipulative and Physiological Therapeutics, 30*(4), 326-330.

Lenschow, R. J. (1998). From Teaching to Learning: A Paradigm Shift in Engineering Education and Lifelong Learning. *European journal of Engineering Education, 23*(2), 155-161.

Lomax, P. (2002). Action Research. In M. Coleman & A. R. J. Briggs (Eds.), *Research Methods in Educational Leadership and Management* (pp. 122-140). London: SAGE Publications.

Love, T. (2000). Theoretical Perspectives, Design Research and the PhD Thesis. In D. Durling & K. Friedman (Eds.), *Doctoral Education in Design: Foundations for the Future* (pp. 237-246). Stoke-on-Trent, UK: Staffordshire University Press.

Malone, S. (2003). Ethics at home: informed consent in your own backyard. *Qualitative Studies in Education, 16*(6), 797-815.

Malterud, K. (2001). Qualitative research: standards, challenges, and guidelines. *The Lancet: Qualitative Research Series, 358*, 483-488.

Markham, T., Larmer, J., & Ravitz, J. (2003). *Project Based Learning Handbook: A Guide to Standards-Focused Project Based Learning for Middle and High School Teachers* (2 ed.). Oakland: Wilsted & Taylor.

Maynard, J., & Smith, V. (2004). Practical ways of improving success in Modern Apprenticeships. *Education and Training, 46*(5), 253-261.

McIntosh, S. (2005). The returns to apprenticeship training. *Journal of Education and Work, 18*(3), 251-282.

McKernan, J. (1996). *Curriculum Action Research: A Handbook of Methods and Resources for the Reflective Practitioner* (2 ed.). London: Kogan Page Limited.

McMorrow, C. (2009, 1st November). Junior Cert may be axed to save €30m. *Sunday Tribune*, p. 1.

McNamee, M. (2002). Introduction: Whose Ethics, Which Research? In M. McNamee & D. Bridges (Eds.), *The Ethics of Educational Research* (pp. 1-21). Oxford: Blackwell Publishers Ltd.

McNiff, J., Lomax, P., & Whitehead, J. (2003). *You and Your Action Research Project* (2 ed.). London: Routledge Farmer.

McNiff, J., & Whitehead, J. (2006). *All You Need to Know About Action Research*. London: SAGE Publications.

Mentkowski, M. (2006). Accessible and adaptable elements of Alverno student assessment-as-learning: Strategies and challenges for peer review. In C. Bryan & K. Clegg (Eds.), *Innovative Assessment in Higher Education* (pp. 48-63). London: Routledge.

Milentijevic, I., Ciric, V., & Vojinovic, O. (2008). Version control in project-based learning. *Computers and Education, 50*, 1331-1338.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook* (2 ed.). London: SAGE Publications Ltd.

Mills, J. E., & Treagust, D. F. (2003). Engineering Education - is Problem-Based or Project-Based Learning the Answer? *Australasian Journal of Engineering Education., online publication, 04*, 1-16.

Moreno-Armella, L., & Waldegg, G. (1993). Constructivism and mathematical education. *International Journal of Mathematical Education in Science and Technology, 24*(5), 653-661.

Morgan, D. L. (1998). *The Focus Group Guidebook* (Vol. 1). London: SAGE Publications Ltd.

Morrison, M. (2002). What do we mean by educational research. In M. Coleman & A. R. J. Briggs (Eds.), *Research Methods in Educational Leadership and Management*. London: SAGE Publications Ltd.

Morton, P., & Wilkinson, S. (2008). Feminist Research. In A. Knight & L. Ruddock (Eds.), *Advanced Research Methods in the Built Environment* (pp. 39-48). Oxford: Wiley-Blackwell.

Muncie, J. (2006). Critical Research. In V. Jupp (Ed.), *The SAGE Dictionary of Social Research Methods* (pp. 51-52). London: SAGE Publications.

Murphy, R. (2006). Evaluating New Priorities for Assessment. In C. Bryan & K. Clegg (Eds.), *Innovative Assessment in Higher Education* (pp. 23-47). London: Routledge.

Musto, J. C. (2001). A project-based approach to teaching numerical methods. *International Journal of Mechanical Engineering Education*, *30*(3), 233-247.

NCCA. (2005). *Review of Mathematics in Post-Primary Education*: National Council for Curriculum and Assesment.

NCCA, & DoE&S. (2002). *Junior Certificate Mathematics Guidelines for Teachers*. Retrieved from http://www.education.ie/servlet/blobservlet/jc_maths_guide.pdf?language=EN .

NCTM. (2009). The National Council of Teachers of Mathematics. Retrieved 19th November 2009, from http://standards.nctm.org/document/chapter2/index.htm

NFQ. (2009a). http://www.nfq.ie/nfq/en/index.html. Retrieved 12th November 2009

NFQ. (2009b). Qualifications Matter : A brief guide to the National Framework of Qualifications. Retrieved 18th December 2009, from http://www.nfq.ie/nfq/en/documents/public_awareness.pdf

NSAI. (2002). National Standards Authority of Ireland, *I.S. 813: 2002 Domestic Gas Installations (Edition 2) - Definitions*. Dublin.

Nunokawa, K. (2005). Mathematical problem solving and learning mathematics: What we expect students to obtain. *Journal of Mathematical Behavior, 24*, 325-340.

Nyhan, B. (2009). Creating the social foundations for apprenticeship in ireland. *Journal of European Industrial Training, 33*(5), 457-469.

O'Connor, L. (2004). *Apprenticeship as a Paradigm of Learning*. Cork: Institute of Technology Apprentice Commission.

O'Connor, L. (2006). Meeting the skills needs of a buoyant economy: apprenticeship - the Irish experience. *Journal of Vocational Education and Training*, *58*(1), 31-46.

O'Connor, L., & Harvey, N. (2001). Apprenticeship training in Ireland: from time-served to standards based; potential and limitations for the construction industry. *Journal of European Industrial Training, 25*(6), 332-342.

O'Connor, L., & Mullins, T. (2005). Introduction. In L. O'Connor & T. Mullins (Eds.), *Apprenticeship as a Paradigm of Learning: Proceedings of the Third Annual ITAC Conference* (pp. 8-14). Cork: Cork Institute of Technology.

Oldfield, N., & Rose, C. (2004). Learning delivers the best return. *Industrial and Commercial Training, 36*(1), 25-28.

Onstenk, J., & Blokhuis, F. (2007). Apprenticeship in the Netherlands: connecting school- and work-based learning. *Education and Training, 49*(6), 489-499.

Onwuegbuzie, A. J. (2000). *Positivists, Post-positivists, Post-structuralists and Post-modernists*. Paper presented at the Association for the Advancement of Educational Research (AAER). Retrieved from http://www.eric.ed.gov:80/ERICDocs/data/ericdocs2sql/content_storage_01/0000019b/80/16/f7/cd.pdf

Opie, C. (2004). *Doing Educational Research*. London: Sage Publications Limited.

Patton, M. Q. (2002). *Qualitative Research & Evaluation Methods* (3 ed.). London: SAGE Publications.

PBLE-Guide. (2003). *A Guide to Learning Engineering Through Projects*.

Pearson, M., Barlowe, C., & Price, A. (1999). *Project-based learning: not just another constructivist environment*. Paper presented at the HERDSA Annual International Conference.

Perakyla, A. (2005). Analysing Talk and Text. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE Handbook of Qualitative Research* (3 ed., pp. 869-886). London: SAGE Publications.

PISA. (2006). *Science Competencies for Tomorrow's World: Ececutive Summary*.

Rabiee, F. (2004). Focus-group interview and data analysis. *Proceedings of the Nutrition Society, 63*, 655-660.

Robinson, A., & Udall, M. (2006). Using formative assessment to improve student learning through critical reflection In C. Bryan & K. Clegg (Eds.), *Innovative Assessment in Higher Education* (pp. 92-99). London: Routledge.

Rowley, J. (2003). Action research: an approach to student work based learning. *Education and Training, 45*(3), 131-138.

Rust, C. (2002). The impact of assessment on student learning. *Active Learning in Higher Education, 3*(2), 145-158.

Ryan, P. (2000). The Attributes and Institutional Requirements of Apprenticeship: Evidence from Smaller EU Countries. *International Journal of Training and Development*, *4*(1), 42-65.

Ryan, P. (2004). The Institutional Requirements of Apprenticeship Training in the Context of the British Isles. In L. O'Connor & T. Mullins (Eds.), *Apprenticeship as a Paradigm of Learning* (pp. 15-34). Cork Institute of Technology, Cork: Institute of Technology Apprentice Commission.

Ryan, P., Gospel, H., & Lewis, P. (2006). Educational and contractual attributes of the apprenticeship programmes of large employers in Britian *Journal of Vocational Education and Training, 58*(3), 359-383.

Schachterle, L., & Vinther, O. (1996). The Role of Projects in Engineering Education. *European journal of Engineering Education, 21*(2), 115-120.

Seezink, A., Poell, R. F., & Kirschner, P. A. (2009). Teachers' individual action theories about competence-based education: the value of the cognitive apprenticeship model. *Journal of Vocational Education and Training, 61*(2), 203-215.

SEFI. (2005). European Society for Engineering Education - Mission Statement. Retrieved 29th November 2009, from http://www.sefi.be/wp-content/uploads/SEFI%20Mission%20Statement%2016.09.05.pdf

Seggern, M. V., & Young, N. J. (2003). The focus group method in libraries: issues relating to process and data analysis. *Reference Services Review, 31*(3), 272-284.

Servan, M. J., Soto, E., Murillo, J. F., Sola, M., & Perez, A. I. (2009). Problem-based learning and action research in postgraduate teaching: the interdisciplinary core. *Educational Action Research, 17*(3), 373-389.

Sikes, P. (2004). Methodology, Procedures and Ethical Concerns. In C. Opie (Ed.), *Doing educational research* (pp. 15-33). London: SAGE Publications Ltd.

Small, R. (2002). Codes are Not Enough: What Philosophy can Contribuit to the Ethics of Educational Research. In M. McNamee & D. Bridges (Eds.), *The Ethics of Educational Research* (pp. 89-110). Oxford: Blackwell Publishers Ltd.

Smith, E. (2002). Theory and practice: the contribution of off-the-job training to the development of apprentices and trainees. *Journal of Vocational Education and Training, 54*(3), 431-456.

Smith, E. (2007). Australian employers' strategies to improve the quality of apprentices. *Education and Training, 49*(6), 459-473.

Smits, H. (1997). Living Within the Space of Practice. In T. R. Carson & D. J. Sumara (Eds.), *Action Research as a Living Practice* (Vol. 67, pp. 281-297). New York: Peter Lang Publishing, Inc.

Somekh, B. (1995). The contribution of action research to development in social endeavours. *British Educational Research Journal, 21*(3), 339-356.

Sparks, A., Ingram, H., & Philips, S. (2009). Advanced entry adult apprenticeship training scheme: a case study. *Education and Training, 51*(3), 190-202.

Speer, S. A., & Hutchby, I. (2003). From Ethics to Analytics: Aspects of Participants' Orientations to the Presence and Relevance of Recording Devices. *Sociology, 37*(2), 315-337.

Stauffacher, M., Walter, A. I., Lang, D. J., Wiek, A., & Scholz, R. W. (2006). Learning to research environmental problems from a functional socio-cultural constructivism perspective. *International Journal of Sustainability in Higher Education, 7*(3), 252-275.

Stewart, R. A. (2007). Investigating the link between self directed learning readiness and project-based learning outcomes: the case of international Masters students in an engineering management course. *European Journal of Engineering Education, 32*(4), 453-465.

Stipek, D. J., Givvin, K. B., Salmon, J. M., & MacGyvers, V. L. (2001). Teachers' beliefs and practices related to mathematics instruction. *Teaching and Teacher Education, 17*, 213-226.

Stringer, E. (2008). *Action Research in Education* (2 ed.). New Jersey: Pearson Education, Inc.

Sumara, D. J., & Carson, T. R. (1997). Reconceptualizing Action Research as a Living Practice. In T. R. Carson & D. J. Sumara (Eds.), *Action Research as a Living Practice* (Vol. 67, pp. xiii-xxxv). New York: Peter Lang Publishing, Inc.

Summit-Skills. (2009). Plumbing Apprenticeships. *The Sector Skills Council for Building Services Engineering* Retrieved 12th November 2009, from http://www.summitskills.org.uk/cgi-bin/go.pl/documents/search.html

Tanggaard, L. (2007). Learning at trade vocational school and learning at work: boundary crossing in apprentices' everyday life. *Journal of Education and Work, 20*(5), 453-466.

Taras, M. (2002). Using Assessment for Learning and Learning from Assessment. *Assessment and Evaluation in Higher Education, 27*(6), 501-510.

Technical-Education. (1961a). The Teaching of Craft Subjects. *Education and Training, 3*(1), 26-27.

Technical-Education. (1961b). The Teaching of Craft Subjects: No. 4 - Drawing, Calculations and English. *Education and Training, 3*(2), 30-52.

Tickle, L. (2002). Opening Windows, Closing Doors: Ethical Dilemmas in Educational Action Research. In M. McNamee & D. Bridges (Eds.), *The Ethics of Educational Research* (pp. 41-57). Oxford: Blackwell Publishers Ltd.

Tomlinson-Committee. (2004). *14-19 Curriculum and Qualifications Reform: Final Report of the Working Group on 14-19 Reform (London, DfES).*

Toner, P. (2008). Survival and Decline of the Apprenticeship System in the Australian and UK Construction Industries. *British Journal of Industrial Relations, 46*(3), 413-438.

Velde, C., & Cooper, T. (2000). Students' perspectives of workplace learning and training in vocational education. *Education and Training, 42*(2), 83-92.

Wellington, J. (2000). *Educational Research: Contemporary Issues and Practical Approaches*. London: Continuum.

Willey, K., & Freeman, M. (2006). Improving Teamwork and Engagement: The case for Self and Peer Assessment. *Australasian Journal of Engineering Education., online publication, 02*, 1-19.

Williams, M. (2006). Positivism. In V. Jupp (Ed.), *The SAGE Dictionary of Social Research Methods* (pp. 229-231). London: SAGE Publications.

Wilson, D. P. (2009). Mathematics is applied by everyone except applied mathematicians. *Applied Mathematics Letters, 22*, 636-637.

Wilson, H. N. (2004). Towards rigour in action research: a case study in marketing planning. *European Journal of Marketing, 38*(3/4), 378-400.

WMA. (2008). World Medical Association Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects. Retrieved 10th January 2010, from http://www.wma.net/en/30publications/10policies/b3/index.html

Young, R. A., & Collin, A. (2004). Constructivism and Social Constructionism in the Carer Field. *Journal of Vocational Behaviour, 64,* 373-388.

Appendices

Plumbing | **Off-the-Job Phases** | **Code 82**

MODULAR PLAN PHASE 6

Total 378 hours

Module 1 Thermal Processes and Pipefitting	Module 2 Advanced Pipework, Water and Waste Water Systems	Module 3 Heating and Air Conditioning	Module 4 Gas Installation
Units 1. Related Safety 2. Manual Arc Welding Fillet Joints 3. Manual Arc Welding Pipe with Flanges 4. Oxy-Acetylene Welding 6 G Position to BS2640 5. T.I.G. Welding of Stainless Pipe 6. Computer Aided Design	**Units** 1. Related Safety 2. Cold Water for Multi-Storey Buildings 3. Hot Water for Multi-Storey Buildings 4. Commissioning of Hot and Cold Services 5. Cause and Control of Legionella 6. Sewage Disposal 7. Rural Water Supply 8. Water Treatment	**Units** 1. Related sSafety 2. Air Handling Units 3. Heating and Cooling Batteries 4. Solar Heating and Heat Pumps 5. Plumbing and Heating Calculations 6. Boilers, Pumps, Pre-Commissioning of Boiler Houses and Heating Systems 7. Sectional Boilers 8. Heating Controls and Introduction to Building Management Systems 9. Pricing and Estimating	**Units** 1. Safety, Legislation and Standards 2. Combustion 3. Flues and Ventilation 4. Installation 5. Pressure and Flow 6. Appliances
Duration 155 hours	**Duration** 44 hours	**Duration** 83 hours	**Duration** 44 hours

NOTE: Durations given on all are guideline only

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Rev 2.2 COC/JON 20/10/06

MODULAR PLAN PHASE 6

Total 378 hours

Module 5
Plant and Process Systems

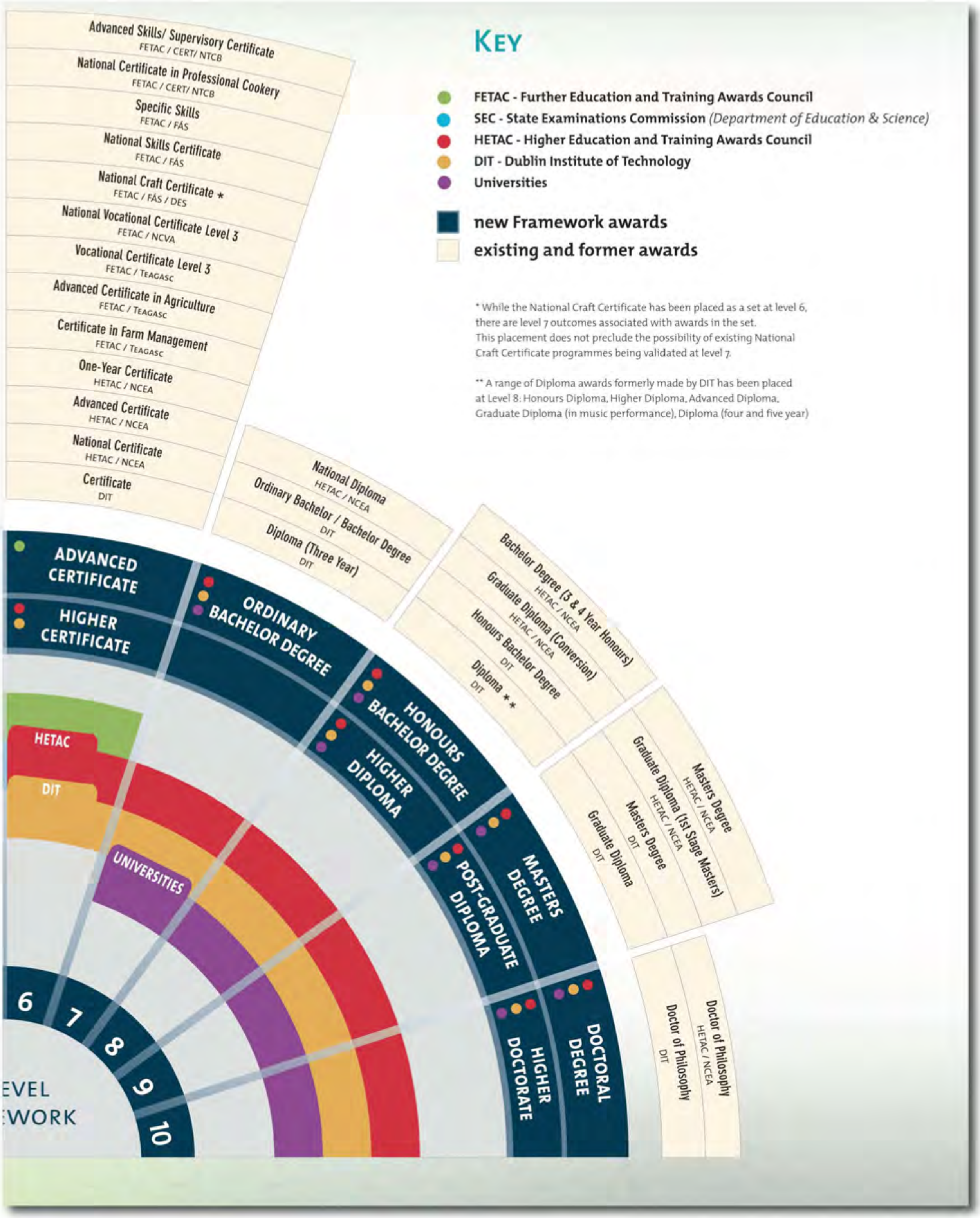
Units
1. Related Safety
2. Fire Prevention Systems
3. Compressed Air/Vacuum/ Medical Gases
4. Steam Processes
5. Building Regulations (Plumbing and Heating)

Duration 52 hours

NOTE: Durations given on all are guideline only

Rev 2.2 COC/JON 20/10/06

Appendix 2: National Framework of Qualifications



Appendix 3: Head of School Approval Letter

Dr Louis Gunnigan
Head of School of Construction
25th October 2009

Dear Dr Gunnigan

As a matter of courtesy I would like to make you aware that I have just commenced the final year of my Masters (MA) in Third Level Learning and Teaching. I am carrying out this project under the guidance of the Dublin Institute of Technology Learning and Teaching Centre.

The provisional title of my thesis proposal is:

Can a deeper understanding and application of Building Services Applied Mathematics be achieved through the implementation of Project Based Learning?

My supervisor for this project is Mr Lloyd Scott from D.I.T. Bolton Street.

I am carrying out this research project using Action Research in an effort not only to improve my own teaching but also to provide a better service to our students and subsequently their employers. It would also be my intention to carry on with this research after the submission of my thesis and extend any positive findings on to other colleagues and students.

During the course of my research it may be necessary to interview staff and students both individually and in focus groups. The students that I will be engaging with for this research year will be a group of Phase Six Plumbing apprentices.

All research will of course be carried out in accordance with any Dublin Institute of Technology ethical guidelines.

In order for me to carry out this research to the best of my ability I am requesting the support of the management and staff of the Department of Construction Skills and Head of School. I have always found this support most forthcoming in the past and I trust will be there in the future.

Should you require any further information regarding this research project please contact me.

Yours sincerely,

____

Kevin Furlong

C.C. Lloyd Scott

Appendix 4: Student Information Document

Project Research Title: ***Can a deeper understanding and application of Building Services Applied Calculations and Mathematics be achieved through the implementation of Project Based Learning within Apprenticeship Education?***

Researcher: Kevin Furlong.

Student Information:

As part of an MA and in an effort to improve the learning and teaching of applied mathematical calculations to Apprentices I am conducting an action research project.

Action research involves changing the way in which something is done with a view to making or recommending improvements. Action research requires all participants including the researcher to be part of the research process in an effort to make these improvements. Through research and recommendations, various implementations may be put in place for further improvements to be made over each cycle of the project.

As part of this research it is my intention to deliver a course of applied mathematical calculations using Project Based Learning as the main platform of teaching and learning. This is being used in an effort to offer students a better understanding of why mathematics are being used within the plumbing trade and also to be able to confidently understand and answer mathematical calculations in national exams at the end of term.

If you have any further queries, concerns or comments regarding this research or the learning of mathematics in general please feel free to contact me

Regards,

Kevin Furlong.

Appendix 5: Student Questionnaire Cover Letter

Project Research Title: ***Can a deeper understanding and application of Building Services Applied Calculations and Mathematics be achieved through the implementation of Project Based Learning within Apprenticeship Education?***

Researcher: Kevin Furlong.

Student Information Survey:

As part of an MA research project and in an effort to improve the teaching and learning of applied mathematical calculations to Apprentices I am compiling an initial anonymous student survey.

This survey is simply to gather information on the feelings of students with regard to the subject of trade calculations and building engineering mathematics in general. The survey being completely anonymous and optional will help to give an indication of students' initial thoughts on trade calculations and maths at the start of their course and subsequently at the end of the term.

As part of this research it is my intention to deliver a course of applied mathematical calculations using Project Based Learning as the main platform of teaching and learning. This is being used in an effort to offer students a better understanding of why mathematics are being used within the plumbing trade and also to be able to confidently understand and answer mathematical calculations in national exams at the end of term.

If you have any further queries, concerns or comments regarding this research or the learning of mathematics in general please feel free to contact me

I would be much obliged if you would complete the attached questionnaire and return it to me at your convenience.

Regards,

Kevin Furlong.

Appendix 6: Focus Group Consent Form

Participant Information Sheet

Project Research Title: ***Can a deeper understanding and application of Building Services Applied Calculations and Mathematics be achieved through the implementation of Project Based Learning within Apprenticeship Education?***

I am currently undertaking an MA in the Dublin Institute of Technology and as part of this research I have given a course of applied mathematical calculations using Project Based Learning as the main platform of teaching and learning. This has been carried out in an effort to offer students a better understanding of why mathematics are being used within the plumbing trade and also to be able to confidently understand and answer mathematical calculations in national exams at the end of term.

I am inviting you to contribute to the research project and in order for you to decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information and contact me if there is anything you would like clarified or if you would like more information. The study will be undertaken in DIT Linenhall and the main aim of the research will be to capture the details of the learning experience of a group of students. I am interested in the experience of students and their feelings and/or apprenhensions in relation to applied calculations and mathematics in general.

It is completely up to you to decide whether or not to take part in the research. Should you decide to take part you will be asked to sign a consent form that is attached for your information. If you do decide to take part but subsequently change your mind you are free to withdraw at any time without giving a reason. The interviews will take place in November and December 2009 and you will be asked to participate in one focus group meeting of about 1 hour in duration.

While there are no immediate benefits for people participating in the project, it is hoped this work will be helpful in terms of providing you with the opportunity to reflect on your learning. If you experience any problems with the research, then please bring this to my attention immediately. If it is not appropriate to address your concerns to me, then you can contact my supervisor, Mr Lloyd Scott, whose contact details are available at the end of this document.

All information collected during the course of the research will be kept strictly confidential and all data will be anonymous so that individuals or the institution cannot be recognised in it. The focus group meeting is being carried out under the guidelines of the Dublin Institute of Technology ethics guiding principals. The results of the research will be used to write my MA thesis, which will be submitted in June 2010. After the thesis is examined it will be stored in the Dublin Institute of Technology Library where it will be accessible to the public. In addition the data collected during the course of the project might be used for a journal article but you will not be identified in any report or publication.

Contact for further information

Kevin Furlong
D.I.T. Bolton Street
Dublin 1

Supervisor
Mr. Lloyd Scott
D.I.T. Bolton Street
Dublin 1

Thank you for reading this and for taking the time to consider participating.

PARTICIPANT CONSENT FORM

Title of Project: ***Can a deeper understanding and application of Building Services Applied Calculations and Mathematics be achieved through the implementation of Project Based Learning?***

Name of Researcher: Kevin Furlong

Please initial box

1. I confirm that I have read and understand the information sheet for the above project and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. ☐

3. I understand that my responses will be anonymous before analysis. I give permission for the researcher and the Supervisor to have access to my anonymous responses. ☐

4. I agree to take part in the above project. ☐

______________________	______________	______________________
Name of Participant	Date	Signature
______________________	______________	______________________
Researcher	Date	Signature

Appendix 7: OECD Definition

Mathematical literacy is defined in the OECD Programme for International Student Assessment (PISA) as “an individual’s capacity to identify and understand the role that mathematics plays in the world, to make well-founded mathematical judgements and to engage in mathematics, in ways that meet the needs of that individual’s current and future life as a constructive, concerned and reflective citizen”
(OECD, 1999).

Appendix 8: Competent Person Scheme

the Institute of Plumbing & Heating Engineering

Summit SKILLS

Minimum Technical Competency of Individuals undertaking Plumbing Installation work

Pb MTC Version 1: 01/07/2007

1

Plumbing MTC Matrix

This Matrix provides the means to demonstrate the Minimum Technical Competency criteria required for Plumbing Competent Person Scheme Entry				
Entry Route (refer to 10.2)	Skills Knowledge	Experience	Ability to Apply Inspection / Assessment On -Site	Off-Site
1	NVQ Level 2 or equivalent + Water Regulations certificate For the installation of unvented cylinders, a current registered operative identity card is required	3 Years (18 months post qualification)	Yes	
Equivalents				
2	Technical Certificate Level 2 + Water Regulations certificate	Portfolio of evidence + experience as above	Yes	
3	C&G Craft Certificate + Water Regulations certificate	Portfolio of evidence, Professional Development + experience as above	Yes	
4	No formal Qualification will require Water Regulations certificate	Completion of the Experienced Plumber Programme	Yes	Yes
5	Current Scheme registrant without entry route 1 requirements	See Entry Routes 2, 3 or 4 above Completion by 29.03.08		

Pb MTC Version 1: 03/07/2007 11

Competent Person Schemes (CPS), that have been designated in Schedule 2A of the Building Regulations, allow registered installers to certify the compliance of controlled work in buildings that are subject to the Building Regulations, removing the need to seek Building Control approval.

Appendix 9: FÁS Apprenticeship Trades

Apprenticeship Listings

FÁS Apprenticeship applies to the following crafts:

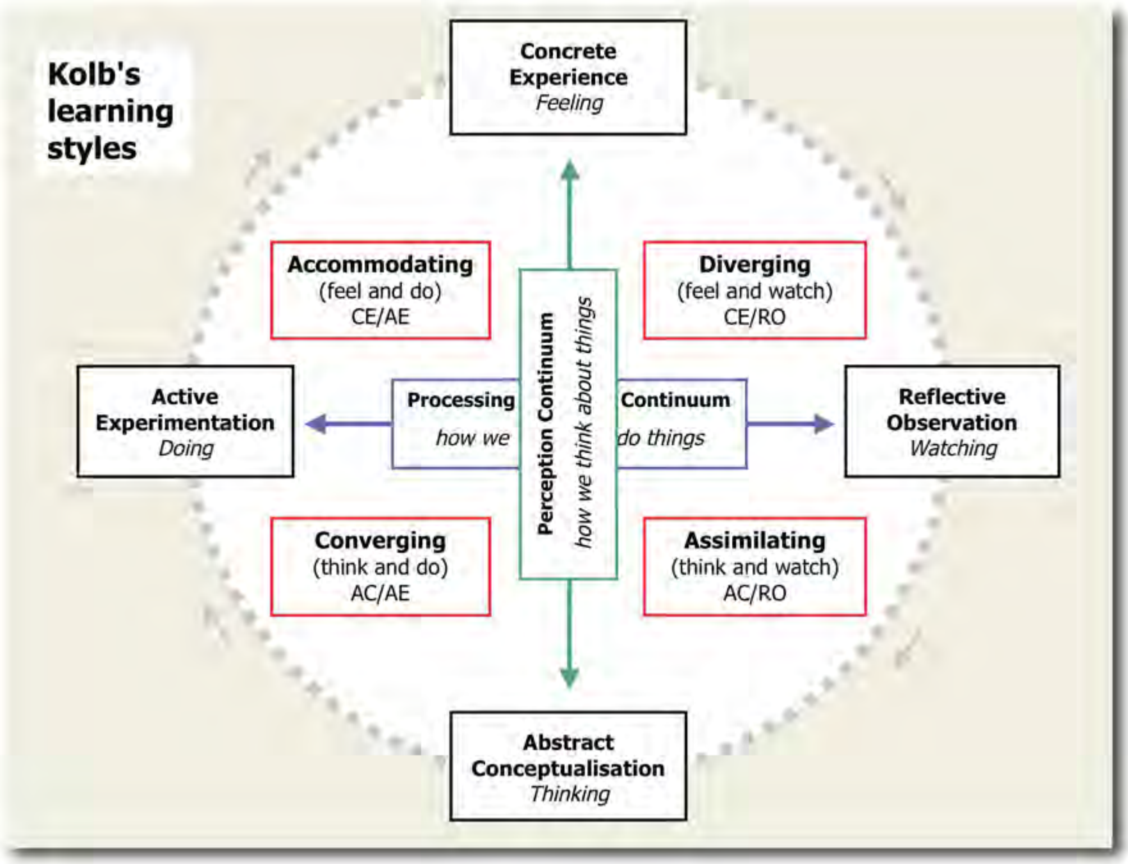
Apprenticeships

Apprenticeship Listings

- The Craft of Agricultural Mechanics
- The Craft of Aircraft Mechanics
- The Craft of Brick/Stone Laying
- The Craft of Cabinet Making
- The Craft of Carpentry & Joinery
- The Craft of Construction Plant Fitting
- The Craft of Electrical
- The Craft of Electrical Instrumentation
- The Craft of Fitting
- The Craft of Floor and Wall Tiling
- The Craft of Heavy Vehicle Mechanics
- The Craft of Instrumentation
- The Craft of Metal Fabrication
- The Craft of Motor Mechanics
- The Craft of Painting and Decorating
- The Craft of Plastering
- The Craft of Plumbing
- The Craft of Print Media
- The Craft of Refrigeration and Air Conditioning
- The Craft of Sheet Metalworking
- The Craft of Toolmaking
- The Craft of Vehicle Body Repairs
- The Craft of Wood Machinery
- The Craft of Electronic Security Systems
- The Craft of Farriery
- The Craft of Industrial Insulation

http://www.fas.ie/en/Training/Apprenticeships/Apprenticeship+Listings/default.htm

Appendix 10: Kolb's Learning Cycle



Appendix 11: PBLE Guide Assessment Methods

8.4 Assessment methods

The assessment method is the process that is applied to determine whether the student has achieved the relevant learning outcome(s).

For project work a range of assessment methods is available. Each method can be used to assess a range of different skills, and be evaluated, either formatively or summatively, by different assessors.

The following table outlines assessment methods that are frequently used within engineering projects, together with skills typically developed, some examples and comments linked to assessment methods, and appropriate personnel to act as assessors.

Method	Skills	Notes	Assessors
Written Report	Knowledge and application of theory Problem-solving Research / Independent learning Writing and desktop publishing	Case Study 6 (Peter Willmot, Loughborough University) describes how the first written project report is the detailed project brief: "We prefer that students are not provided with a detailed written brief as the first task is for the team to get to grips with the problem and generate their own detailed specification."	Tutors External assessors
Product, prototype or model	Problem-solving Design and manufacture	Depending upon the learning outcomes this can be assessed on a wide range of criteria including aesthetics, ergonomics, quality, design.	Tutor Peers Practising engineer
Performance Testing / Product Performance	Evaluation	Where the project has a physical end product, performance testing may be the most relevant assessment method. Project diaries and lab books can record progress and methodology and contribute a part of the final mark	Tutor
Learning log / diary	Independent learning	Style and structure should be clearly specified as there are a wide variety of formats eg templates completed for each task. By scheduling regular progress reports students will reflect on their progress to date and can receive invaluable feedback to help them progress.	Tutor Peers Mentors

Method	Skills	Notes	Assessors
Viva voce	Understanding Communication Reasoning	The viva voce examination should be structured and objective. Gives students the opportunity to verbally support their work and to defend it. This situation closely parallels work based scenarios.	Tutor Practising engineer
Presentation	Knowledge Understanding Ability to structure information and oral communication skills	Models a common work based scenario, questions from peers, tutors and employers can provide useful formative feedback.	Tutors Self Peers engineer
Poster	Presentation Communication Knowledge and application of theory	At some institutions students present a mid project poster with staff and students present and asking questions. Attendance by students from earlier levels can generate interest, add an element of competitiveness, indicate scope and what can be attained and ensure they start considering the project at an early stage.	Tutors Peers Practising engineer
Portfolio	Creativity Computer aided design skills.	A portfolio is more than a report and incorporates a number of project outputs. Often used for conceptual design projects. Increasingly these portfolios are containing diagrams from CAD and 3D modelling packages, which may be supported by initial designs and sketches	Tutors Mentor Peers Practising engineer
Written examination	Knowledge based skills Numerical skills	Pre-seen scenario open book examinations may be suitable for assessment, but traditional written exams are often not appropriate to assess many of the learning outcomes that result from projects.	Tutors

It is common that a number of different assessment methods and outputs are used within one project and it is important that these are appropriately weighted and scheduled to ensure ongoing student motivation and a manageable workload. Note: the choice of assessment method will determine the assessment workload.

Appendix 12: Student Questionnaires

MA in Third Level Learning and Teaching		Student Questionnaire October 2009

Start of Term Student Questionnaire:

Please do <u>not</u> include your name on this questionnaire:

Survey Questions: Please tick the appropriate box and include your own comments if necessary.

1. When have you last studied any mathematical calculations

Within the past year ☐

Within the past three years ☐

Not since Phase Four ☐

Not since School ☐

Other:____

____

2. What level of mathematics did you study at school

Junior Certificate ☐

Leaving Certificate ☐

Higher Level Leaving Certificate ☐

Other:____

____

2		Compiled by Kevin Furlong

3. At what level would you consider your current understanding of mathematics

Average ☐

Good ☐

Advanced (higher level Leaving Certificate) ☐

Other:____

4. When have you last used any mathematical calculations in your line of work

Within the past six months ☐

Within the past year ☐

Never ☐

Other:____

5. Do you think that mathematical calculations are an essential part of your trade

Yes ☐

No ☐

Reason:____

6. Would you like to know more about the mathematics and calculations used in your trade

Yes ☐

No ☐

Reason:____

7. Have you ever used mathematical calculations to design any part of a plumbing system

Yes ☐

No ☐

Other:____

8. Have you ever enjoyed learning mathematics in the past

Yes ☐

No ☐

If yes can you give a reason:____

9. Have you any fear of learning mathematics

Yes ☐

No ☐

If yes can you give a reason: ____

10. Would you rather if mathematical calculations were not included in this course

Yes ☐

No ☐

Reason:____

11. If you do not like mathematics would you put it down to any of the following

The way it was taught to you ☐

You could not understand it ☐

You had no interest in it ☐

You could not relate them to your trade ☐

If none of the above please specify: ____________________

____

____

12. Do you feel that your current understanding of applied trade mathematical calculations could hold you back in your future career

Yes ☐

No ☐

Other: ____________________

____

End of Term Student Questionnaire:

Please do not include your name on this questionnaire:

Survey Questions: Please tick the appropriate box and include your own comments if necessary.

1. Before this project-based course when have you last studied any mathematical calculations

Within the past year ☐

Within the past three years ☐

Not since Phase Four ☐

Not since School ☐

2. Having done this course do you now feel more confident about using trade calculations

Yes ☐

No ☐

Just the same ☐

Other:____

3. Would you consider your current understanding of mathematics has improved since doing this course

Yes ☐

No ☐

Has remained the same ☐

Other:____

4. When have you last used any mathematical calculations in your line of work

Within the past six months ☐

Within the past year ☐

Never ☐

Other:____

5. Would you now feel confident about using maths in your line of work

Yes ☐

No ☐

Reason:____

6. Would you now like to know some more about the mathematics and calculations used in your trade

Yes ☐

No ☐

Reason:____

7. Have you ever used mathematical calculations to design any part of a heating or plumbing system

Yes ☐

No ☐

Other:____

8. Would you now feel that you could use some calculations to design a part of a heating or plumbing system

Yes ☐

No ☐

Can you give a reason:____

____

____

9. Have you enjoyed learning mathematics in this course

Yes ☐

No ☐

Can you give a reason:____

____

____

10. Have you any fear of learning mathematics

Yes ☐

No ☐

If yes can you give a reason: ____

____

____

11. Would you rather if mathematical calculations were not included in this course

Yes ☐

No ☐

Reason:____

____

12. Did you think that the way maths were taught to you in this course was better or easier to understand than you did before

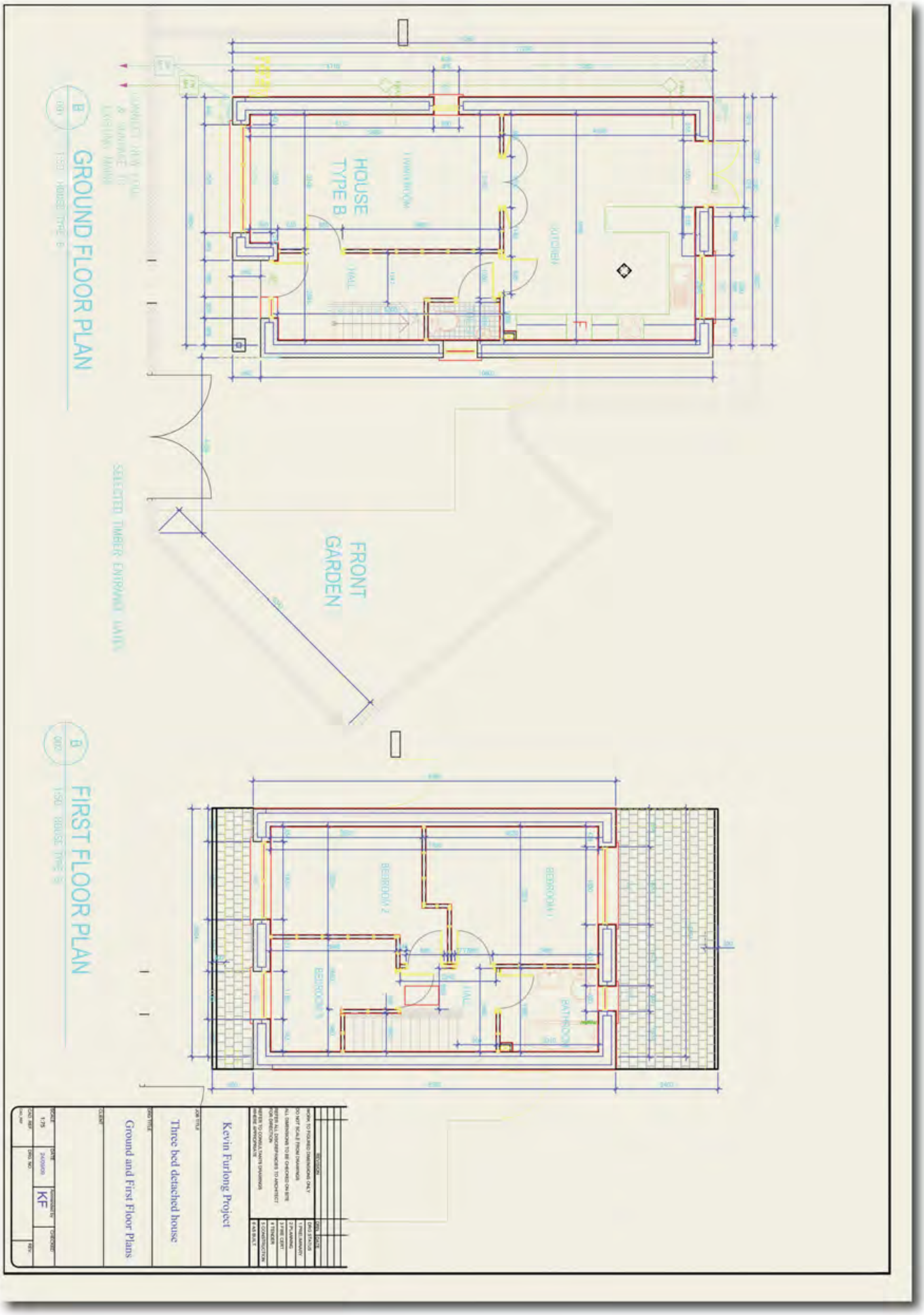
Yes ☐

No ☐

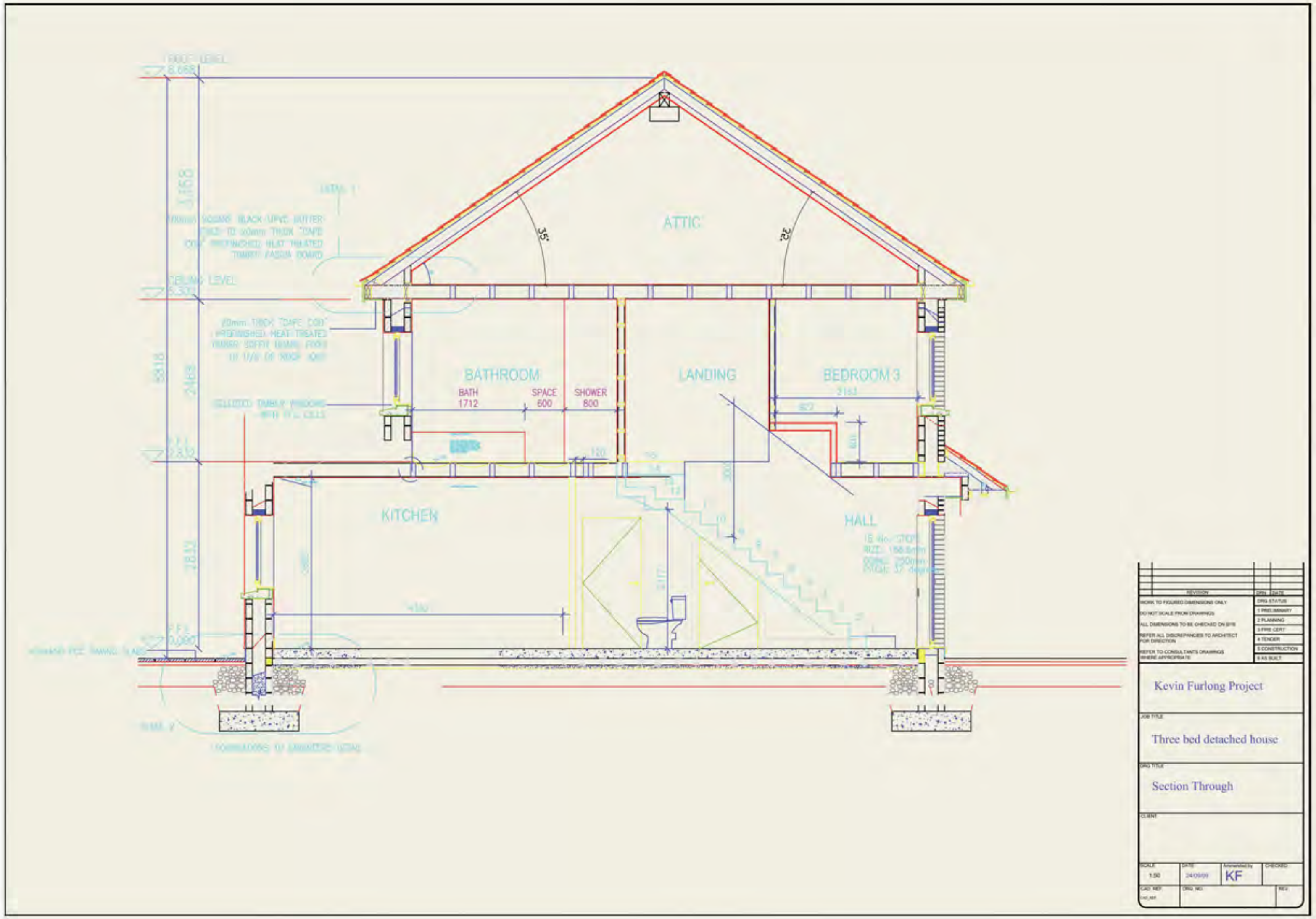
Reason:____

____

Appendix 13: Student Project Plans and Elevations




FRONT ELEVATION
1:50 HOUSE TYPE B
REAR ELEVATION
1:50 HOUSE TYPE B
ROOF LEVEL 8.465
CEILING LEVEL 5.300
F.F.L. 2.850
CEILING LEVEL 2.600
F.F.L. 0.000
2850
2450
3165
8465
SELECTED BLACK CONCRETE ROOF TILES
SELECTED TIMBER WINDOWS WITH PCC CILLS
SELECTED TIMBER DOORS
SELECTED COLOUR BRICK TO MATCH ADJACENT NEW HOUSES
SELECTED COLOUR SAND/CEMENT RENDER
PASSIVE STACKS FOR NATURAL VENTILATION
Kevin Furlong Project
Three bed detached house
Elevations
KF



ROOF LEVEL
8.668
3358
CEILING LEVEL
5.300
5318
2468
2832
ATTIC
35°
35°
BATHROOM
BATH
1712
SPACE
600
SHOWER
800
LANDING
BEDROOM 3
KITCHEN
HALL
REVISION
WORK TO FIGURED DIMENSIONS ONLY
DO NOT SCALE FROM DRAWINGS
ALL DIMENSIONS TO BE CHECKED ON SITE
REFER ALL DISCREPANCIES TO ARCHITECT FOR DIRECTION
REFER TO CONSULTANTS DRAWINGS WHERE APPROPRIATE
DRG STATUS
Kevin Furlong Project
JOB TITLE
Three bed detached house
DRG TITLE
Section Through
CLIENT
SCALE
1:50
DATE
KF
CHECKED
CAD REF
DRG NO
REV

Appendix 14: Sample Project Calculations

Plumbing Calculations Project – Sheet No. 1

Using recommended trade calculations for **Area, Volume** and **Capacity** within your project house; determine the following:

Area: (m^2)

1. The living room, hall and kitchen are to be heated using underfloor heating pipework, find the following;
2. The amount of pipe to be ordered if you need 5m of pipe per m^2 of floor area.
3. The total amount of heat emitted into the room if the output from the underfloor heating installation is $100W/m^2$.
4. The areas of all the walls, floors and ceilings upstairs will need to be known to work out the radiator sizes for these rooms later on – number all of these fabrics and get the areas of them.

Volume: (m^3)

5. The concrete covering the underfloor heating pipework is required to 120mm thick. How much concrete will need to be ordered for this job.
6. The volume of all the rooms upstairs will need to be known in order to work out the radiator sizes for these rooms later on – name all of these rooms and get the volume of each of them.
7. An extract fan is required for the downstairs toilet. In order to select the correct fan the volume of air in the room is needed. Calculate the total volume of air in this room.

Capacity: (Litres)

8. The cold water storage cistern is to be situated within the attic space. The recommended storage capacity is 100 litres per bedroom; calculate the size of the cistern required. An allowance of 150mm should be made for the actual capacity.
9. Calculate the weight of the cold water storage cistern when it is full.

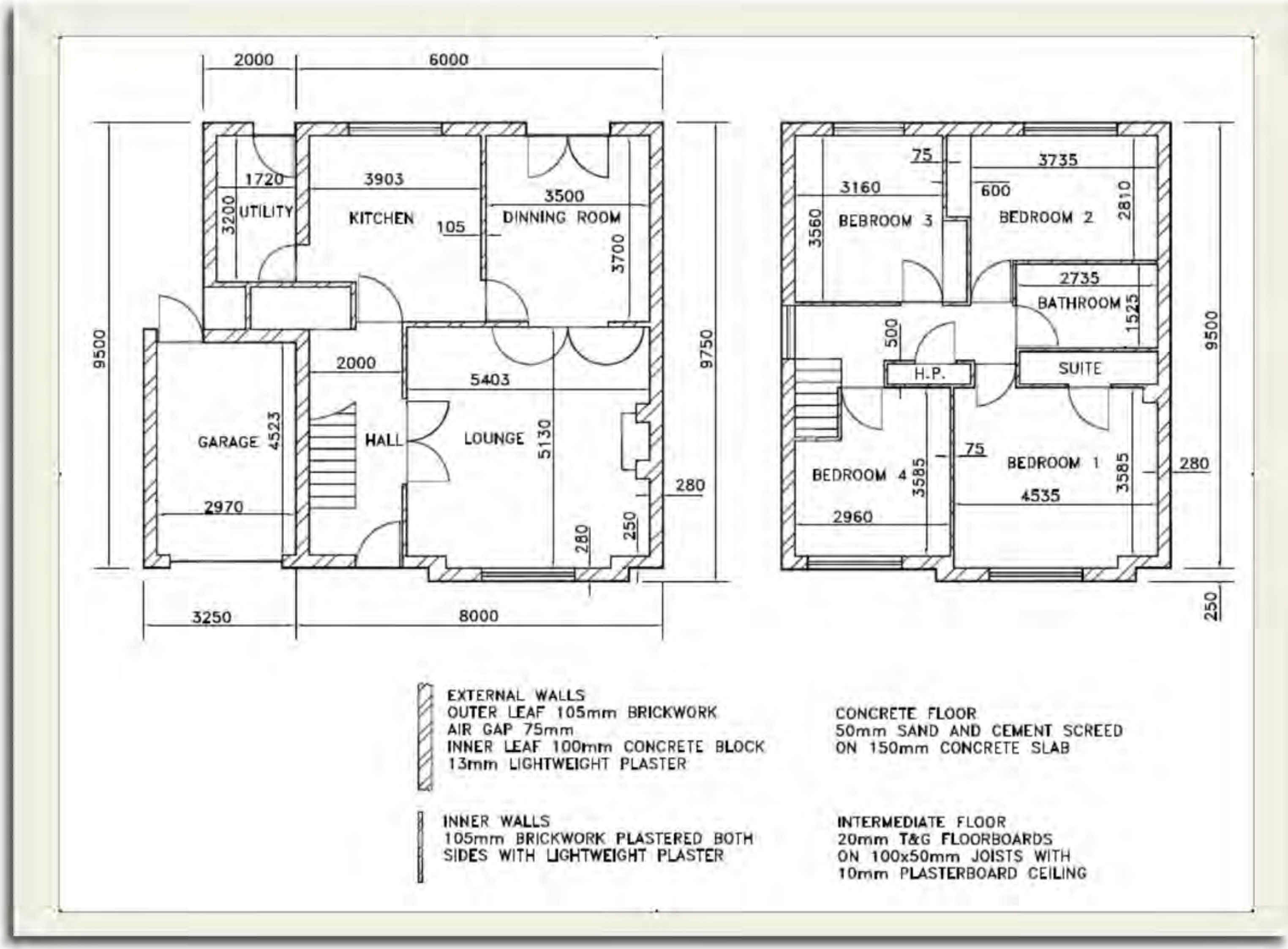
10. A cylindrical oil storage tank is installed outside the house to feed the oil fired boiler. It measures 3.15m long and 1800mm in diameter. How much oil will need to be ordered to fill this tank.

11. If the oil tanker is delivering oil at a rate of 4 litres per second, how long will it take to fill the oil tank.

12. An indirect hot water storage cylinder is to be fitted under the stairs. It measures 900mm in diameter and 1.2m in height; what is the capacity of the cylinder if the heating coil within takes up $0.2m^3$ of space.

This self assessment worksheet comprises just a few of the plumbing calculations that can be worked out by using the simple formulas for area, volume and capacity.

More plumbing calculations will follow on the next self assessment sheet.


2000
6000
1720
3903
3500
UTILITY
KITCHEN
DINNING ROOM
3200
105
3700
2000
5403
GARAGE
4523
HALL
LOUNGE
5130
2970
280
250
280
9500
9750
3250
8000
75
3735
3160
600
BEBROOM 3
BEDROOM 2
3560
2810
2735
BATHROOM
1525
500
H.P.
SUITE
75
BEDROOM 4
3585
BEDROOM 1
4535
3585
2960
280
9500
250
EXTERNAL WALLS
OUTER LEAF 105mm BRICKWORK
AIR GAP 75mm
INNER LEAF 100mm CONCRETE BLOCK
13mm LIGHTWEIGHT PLASTER
CONCRETE FLOOR
50mm SAND AND CEMENT SCREED
ON 150mm CONCRETE SLAB
INNER WALLS
105mm BRICKWORK PLASTERED BOTH
SIDES WITH LIGHTWEIGHT PLASTER
INTERMEDIATE FLOOR
20mm T&G FLOORBOARDS
ON 100x50mm JOISTS WITH
10mm PLASTERBOARD CEILING

Appendix 15: Focus Group Questions

Project Research Title: ***Can a deeper understanding and application of Building Services Applied Calculations and Mathematics be achieved through the implementation of Project Based Learning within Apprenticeship Education?***

Researcher: Kevin Furlong.

Student Information Focus Group:

Introduction:

The reason I am carrying out this research is in an effort to improve the way in which maths and then hopefully other subjects are taught and more importantly understood. This is an informal focus group where your comments are much valued.

What I want to find out is the following,

1. Before the start of this course (phase six plumbing) when did you last use calculations or maths?
2. Before this course how was your understanding or feelings about maths, had you any apprehension regarding calculations or maths.
3. How were maths taught to you previously.
4. If you could do the maths previously were you able to relate them and use them in your line of work.
5. We have gone through 4 areas of maths, namely….
6. Taking each in detail and applying them to the project house, how did you feel that this worked, was it more interesting or worthwhile.
7. After going through this PBL method do you feel any more confident about your understanding of maths?

8. Would you now feel more confident about using these calculations in your line of work?

9. Can you now see the value or relevance of applied mathematics and how they are important in your trade?

10. Would you be inclined to use these calculations now if you needed to on site?

11. Would you have any suggestions as to how I might improve this type of teaching and learning?

12. Would you like to see more or all subjects being taught using real projects.

13. Would you like to see more or all assessments / exams carried out using projects with subjects dropping off rather than accumulating.

14. For what reason – easier or better value for understanding your trade?

15. Have you any intention of progressing to further education?

16. Any other comments or suggestions?

Appendix 16: Typical Phase Six Timetable

SCHOOL OF CONSTRUCTION - DIT BOLTON STREET
DEPARTMENT OF CONSTRUCTION SKILLS
CLASS TIMETABLE – 2009/10

TRADE:- Plumbing PHASE:- 6 GROUP:-1 TERM :-3

START DATE:- 7th April 2010 FINISH DATE:- :- 18th June 2010

DRAFT

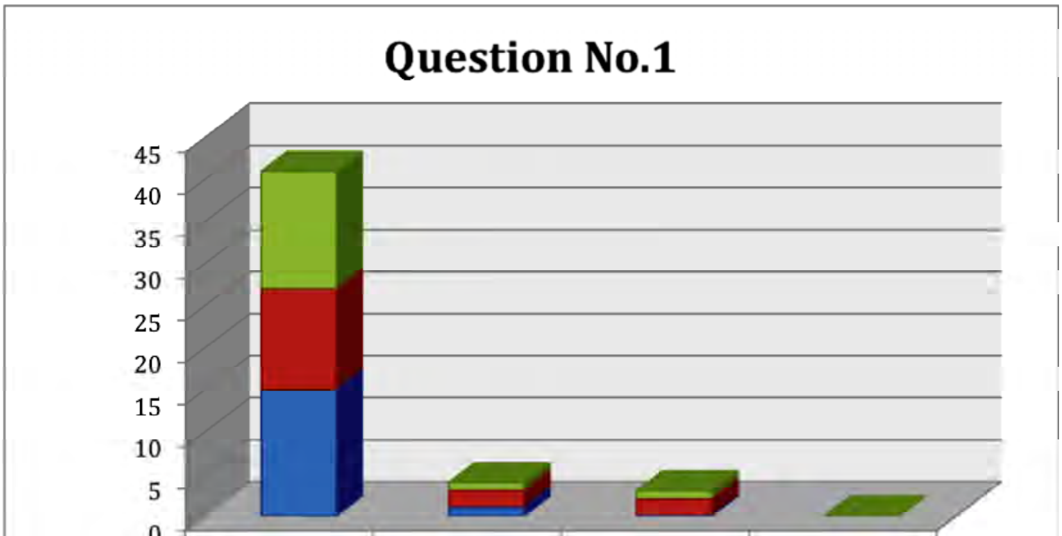
DAY	TIME	SUBJECT	LECTURER	ROOM
MONDAY	9.00 – 12.30	M.M.A. Welding	J. Donohue	219
	1.30 – 5.00	Oxy-acetylene Welding	M. McKeogh	16
TUESDAY	9.00 – 12.30	Electrical controls	M. McKeogh	133
	1.30 – 5.00	Technology	F. McGuinness	302
WEDNESDAY	9.00 – 12.30	Oxy-acetylene Welding	K. Furlong	16
	1.30 – 5.00	Technology	K. Furlong	302
THURSDAY	9.00 – 12.30 11.30 – 12.30	Technology General Studies	D. Cummins D. McGarty	214 214
	1.30 – 5.00	Technology	M. Nicholson	208/01
FRIDAY	9.00 – 12.30	Technology	D. Cummins	302
	1.30 – 5.00	Technology	M. Nicholson	116

Lecturer with responsibility for Register: M. Nicholson

Signed:-______________ Date:-____________

Appendix 17: Graphical & Descriptive View of Student Questionnaires

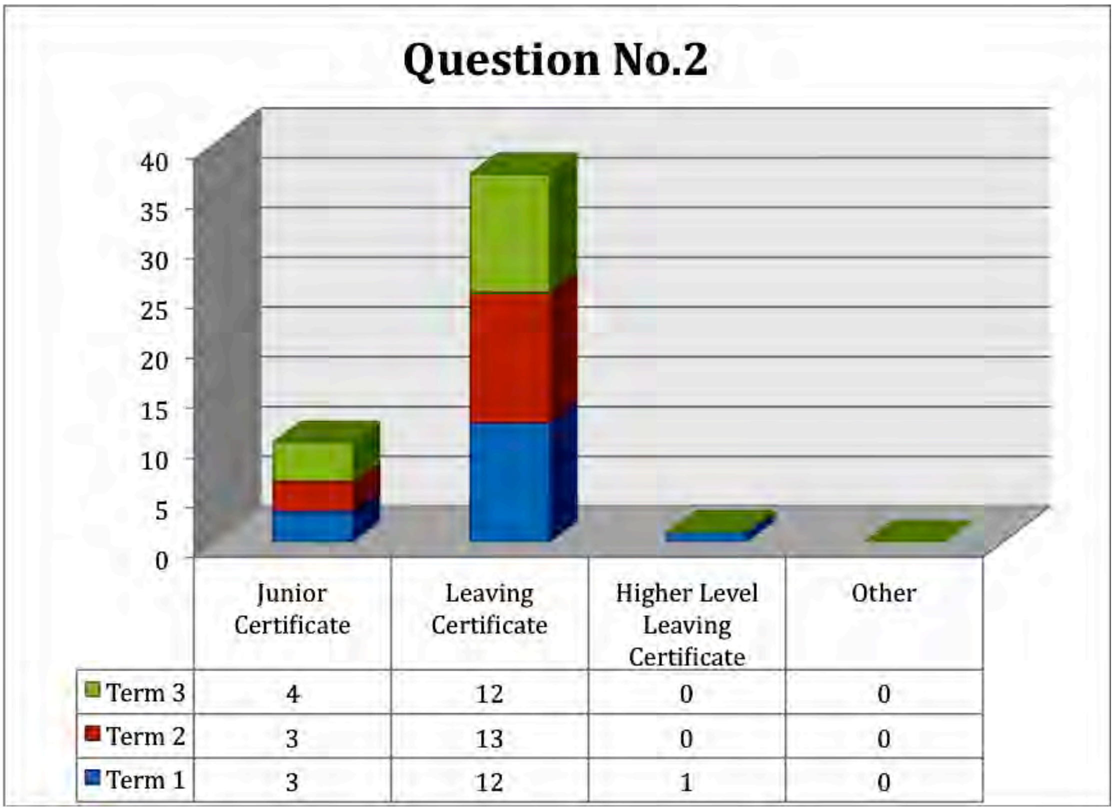
Question No. 1; *When have you last studied any calculations or mathematics*; was included in an effort to establish if any of the students had chosen to study mathematics relevant to their craft since last attending off-the-job studies or as far back as school level. The responses to this question are shown graphically below.



	Not Since Phase Four	Within the Past Year	Within the Past Three Years	Not Since School
Term 3	14	1	1	0
Term 2	12	2	2	0
Term 1	15	1	0	0

It can be seen from the above responses that the majority of the participants over the three terms had chosen not to engage with calculations or applied mathematics since phase four of their training and education. During later focus group sessions it was the general opinion of those who had studied mathematics since phase four, did so to a very basic level, i.e. working out areas and basic measurement arithmetic.

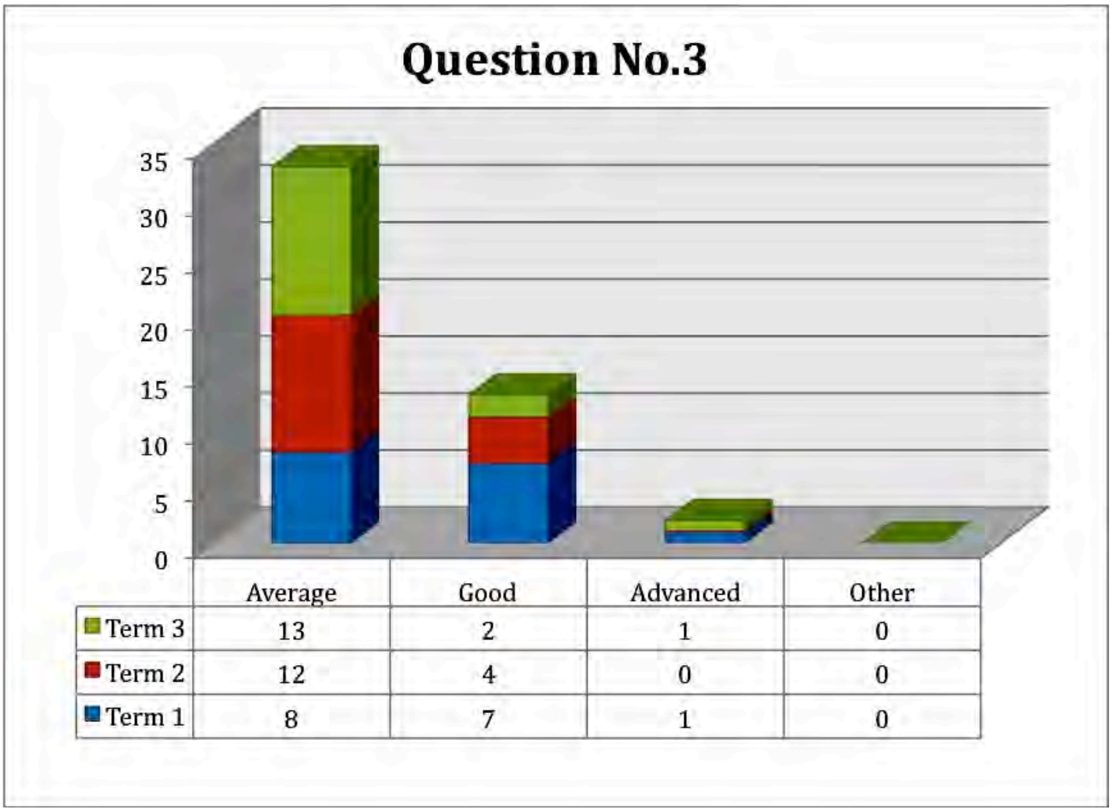
Question No. 2; W*hat level of mathematics did you study at school*; was included to link into question No. 3 and establish if the students perceptions of applied craft calculations and mathematics was any different if a higher level of second level education was achieved. The responses to this question are shown graphically below.



	Junior Certificate	Leaving Certificate	Higher Level Leaving Certificate	Other
Term 3	4	12	0	0
Term 2	3	13	0	0
Term 1	3	12	1	0

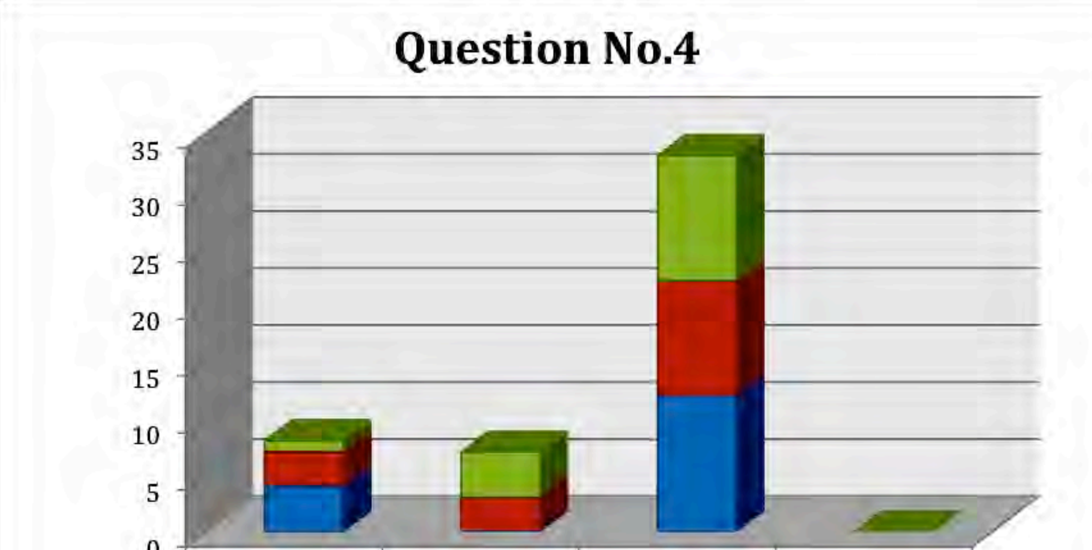
From my previous experience in company management and recruitment I found the responses to this question surprising. It had been my experience that the majority of applications for apprenticeship came from those who had decided to leave second level education after completing the Junior Certificate. However, the responses here spread over three terms suggest that this trend has changed with the majority of student apprentices now holding a Leaving Certificate. With the current economic downturn and the related slow-down within the construction industry, it will be interesting to monitor how this trend will be affected over the next year or two.

Question No. 3; At w*hat level would you consider your current understanding of mathematics*; was included firstly to link to question No. 2 and also to begin to get a feeling of the level of mathematical ability of these students' prior to embarking on the project based learning paradigm. The responses to this question are shown graphically below.



It is interesting to note here that although the majority of participants held a Leaving Certificate most would consider their current mathematical skills as only average. During focus group sessions the main reason given for this was the way in which they were taught on the subject both at second level and phase four of their apprenticeship. This would also correspond to findings made in the literature review of Chapter Two.

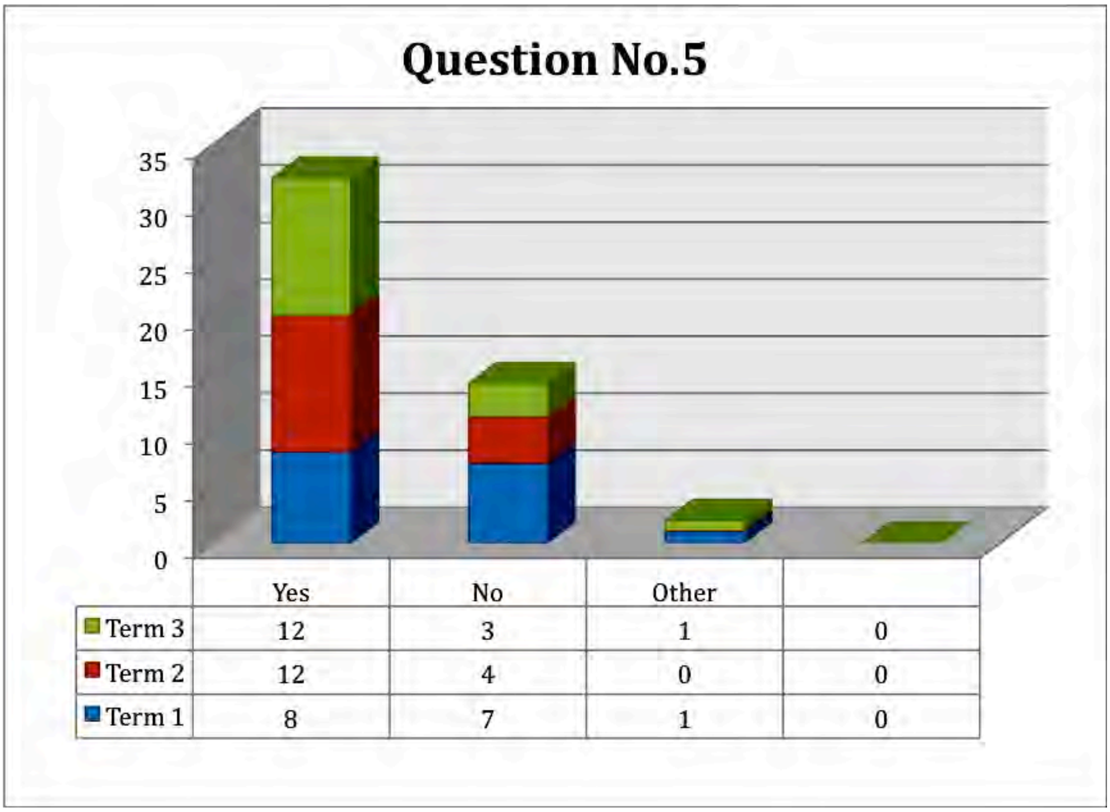
Question No. 4; *When have you last used any mathematical calculations in your line of work*; was included to get an understanding of the use made of craft mathematics and calculations on site and the abilities of the participating students to implement them. The responses to this question are shown graphically below.



	Past Six Months	Past Year	Never	Other
Term 3	1	4	11	0
Term 2	3	3	10	0
Term 1	4	0	12	0

The period between phase four and six of the plumbing apprenticeship for most of the participants represented a period of about eighteen months. By the time these apprentices reach phase six they have on average spent almost four years in training. What emerged from this initial questionnaire is that within this time, very few of these students have ever used calculations within their line of work. Focus group interviews later revealed strong opinion from participants that they could not relate what they had learned in either phase two or four of their apprenticeship, to practical applications on site. This also emerged very evidently from observational records of classroom sessions.

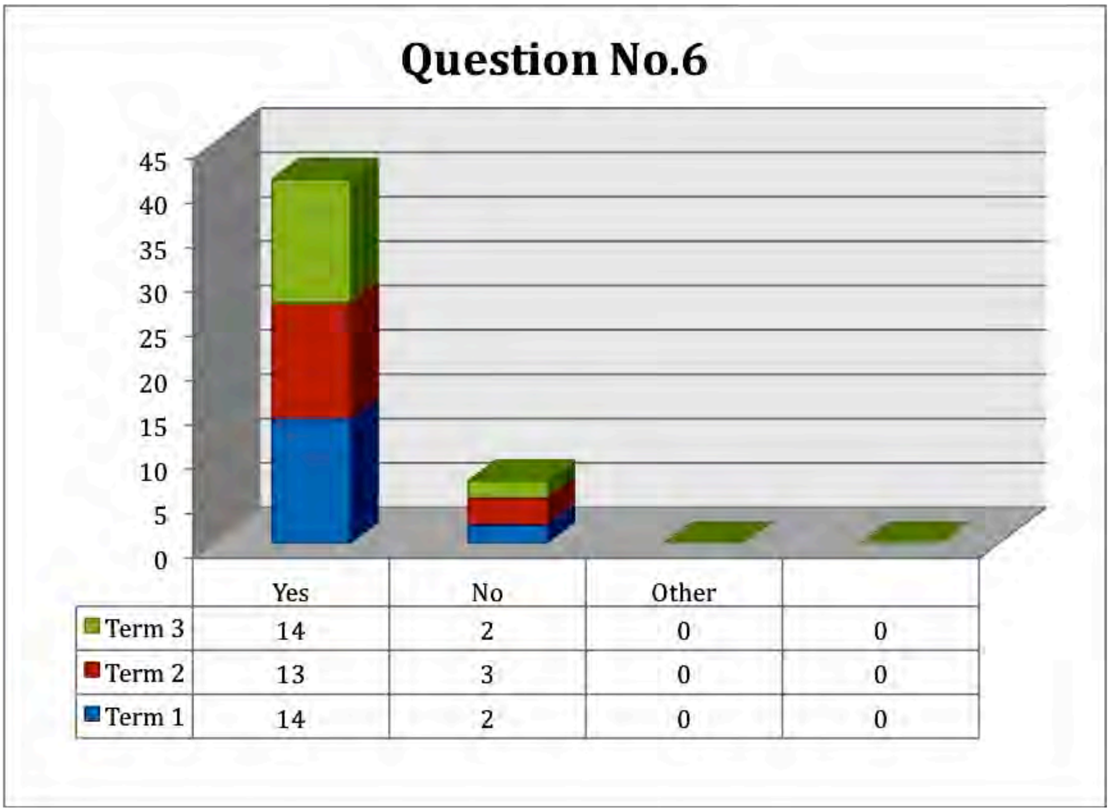
Question No. 5; *Do you think that mathematical calculations are an essential part of your trade*; was included to get a perception on the level of importance that craft calculations are given by students in the overall context of the trade. The responses to this question are shown graphically below.



	Yes	No	Other	
Term 3	12	3	1	0
Term 2	12	4	0	0
Term 1	8	7	1	0

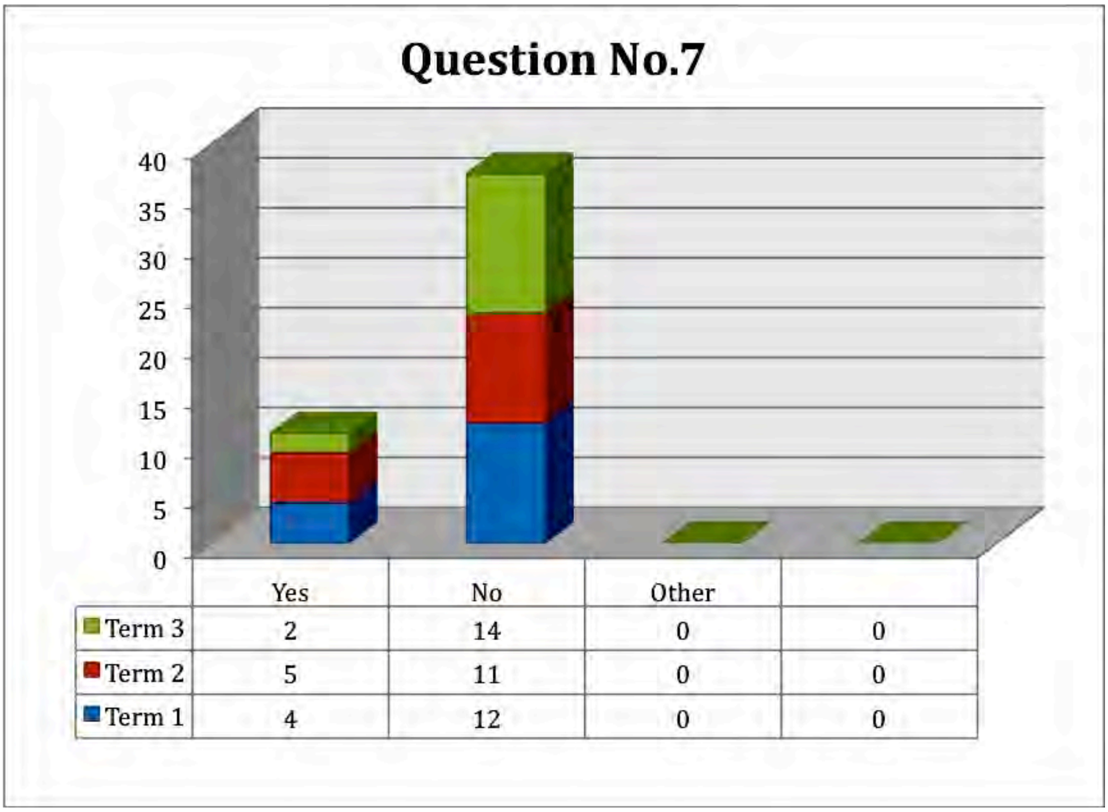
A mixed reaction to this question suggested that most students knew mathematics were an essential part of their trade, but as later observations and interviews revealed many did not understand where or how to apply them in real working situations.

Question No. 6; *Would you like to know more about mathematics and calculations used in your trade*; this was included to gain a perspective on the student apprentices willingness to learn more about their craft and in particular craft mathematics. The responses to this question are shown graphically below.



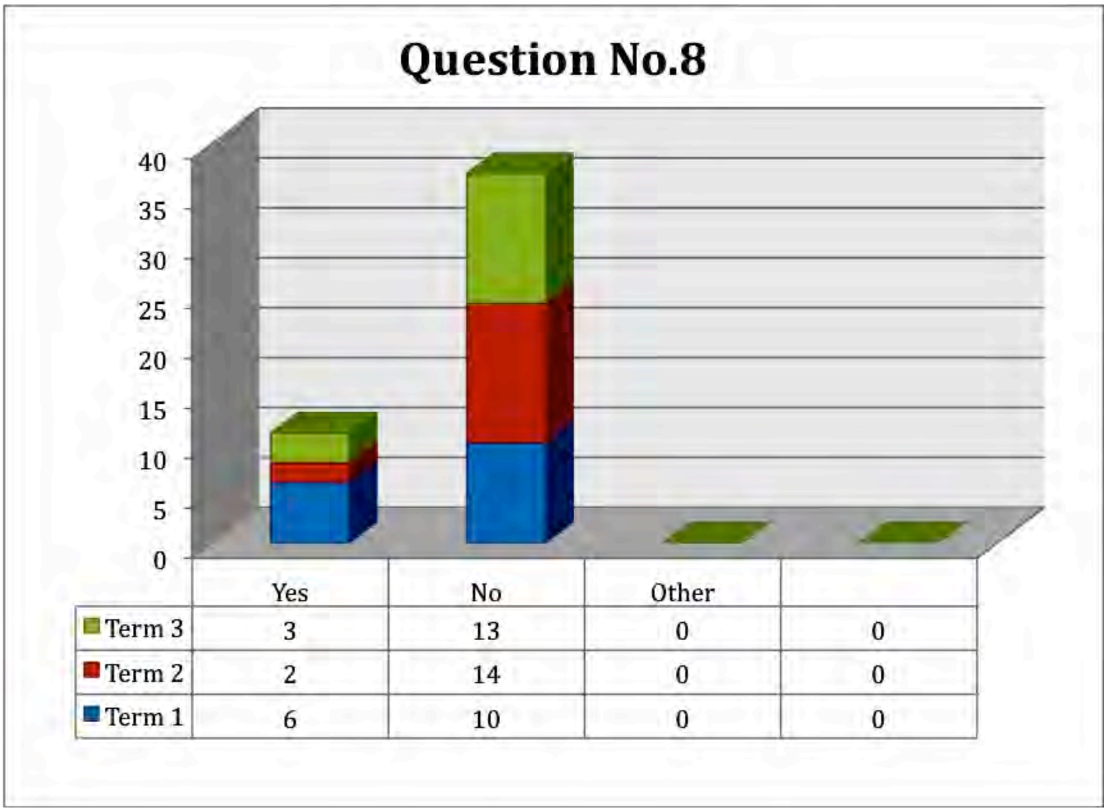
From the responses to the previous two questions it can be suggested that these students were aware that applied mathematics and calculations are an important part of their craft and they were willing to learn more about them. However, further research data suggests that where these students cannot see a clear link between these calculations and real-world situations they lose interest in engagement with them.

Question No. 7; *Have you ever used mathematical calculations to design any part of a plumbing system*; this links back to question No. 4, in an attempt to establish the level of mathematical calculations that students have used before in their line of work. The responses to this question are shown graphically below.



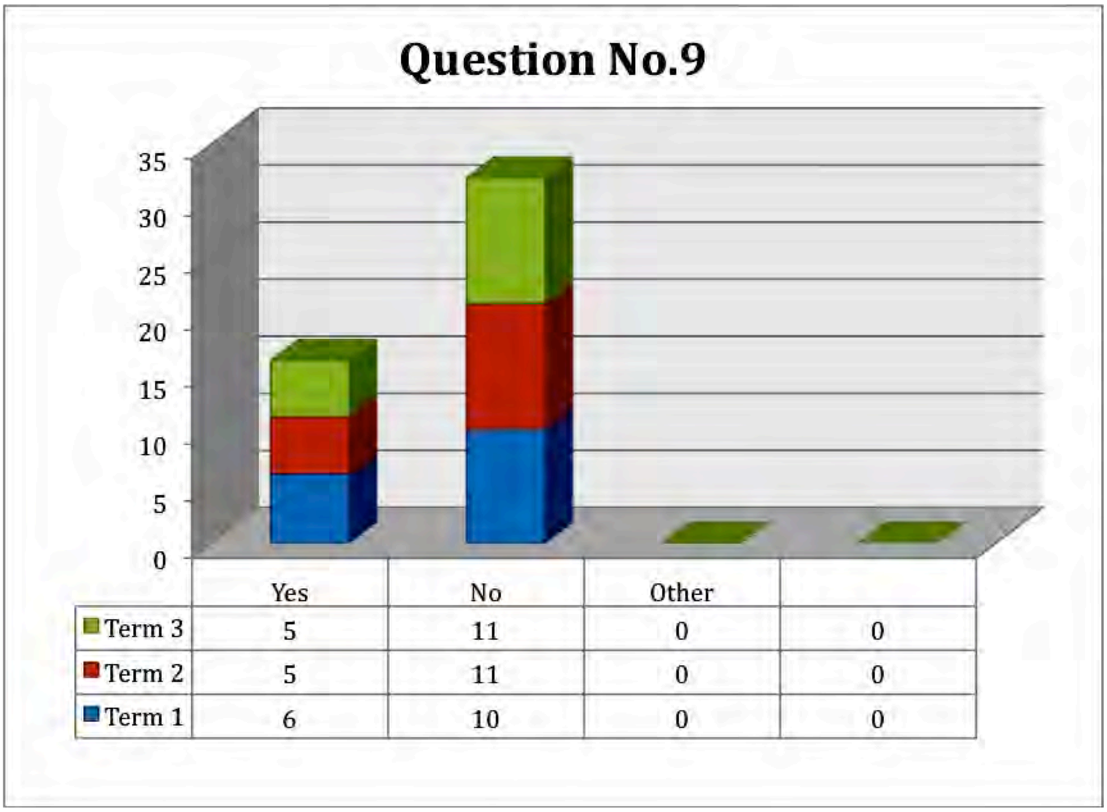
The responses to the previous three questions show mixed feelings on the level of importance given to craft mathematical calculations, but yet significant interest in learning more about those mathematics applicable to their trade. As mentioned in question No. 4 above, focus group sessions also revealed a strong opinion from participants that they could not relate the mathematical theory they had learned in either phase two or four to practical applications on site. This again emerged very evidently from observational records of classroom sessions.

Question No. 8; *Have you ever enjoyed learning mathematics in the past*; this question was submitted in order to get an idea of students past experiences of mathematics which subsequently links to the end of term questionnaire. A space for qualitative reasons was also included with this question. The responses to this question are shown graphically below.



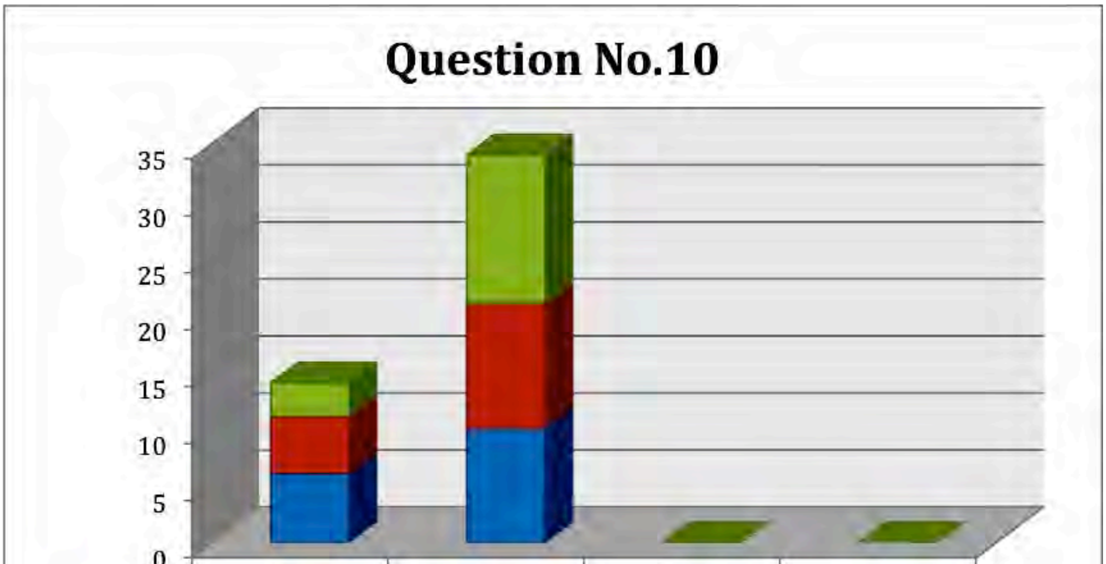
Focus group sessions further revealed strong opinion from participants that they could not relate what they had learned in phase two or four to practical applications on site, thus lessening the enjoyment value. The majority of their second level mathematical experiences also appear to reflect those discussed in the review of the literature as being unrelated to real-life and mainly based on rote learning. These feelings also emerged very evidently from observational records of classroom sessions and within focus group interviews.

Question No. 9; *Have you any fear of learning mathematics*; this question also links to question No. 8 in an effort to establish if past mathematical experiences have had an effect on the students current confidence to engage with mathematics and calculations within their trade. The responses to this question are shown graphically below.



A mixed response to this within focus group sessions suggest that past experiences of learning mathematics have made some students fearful of mathematics. Teaching methods leading to an inability to understand the subject appeared as a major factor for those who had a fear of learning mathematics. I found it encouraging however, that most of the participants over the three terms did not display any fear of further or deeper learning within this area.

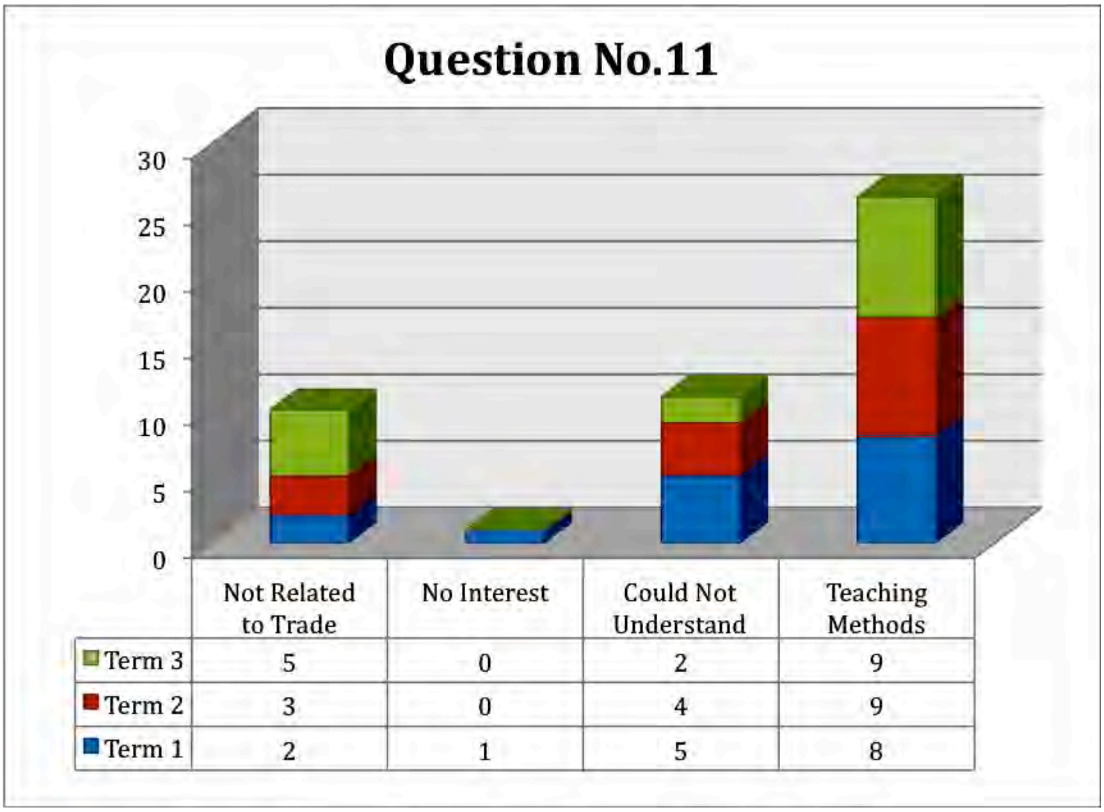
Question No. 10; *would you rather if mathematical calculations were not included in this course*; this question links back to question No. 6 to further establish the student apprentices willingness to embrace and learn applied calculations as part of their craft. The responses to this question are shown graphically below.



	Yes	No	Other	
Term 3	3	13	0	0
Term 2	5	11	0	0
Term 1	6	10	0	0

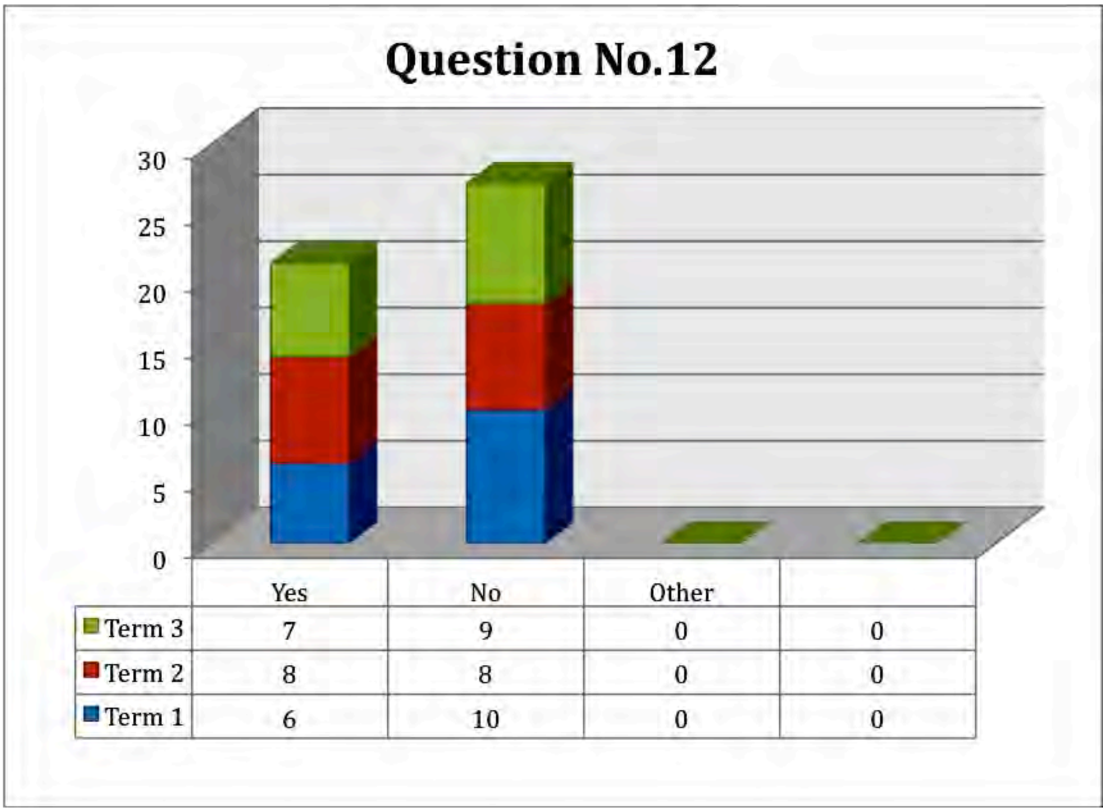
It was interesting to note that the reason given for a ‘yes’ answer on the questionnaires was cited mainly as; they could never see any use for mathematics or know where to apply them in their line of work. However, it was again encouraging to see so many students willing to learn more about mathematical calculations related to their craft.

Question No. 11; *if you do not like mathematics would you put it down to any one of the following*; this question links back to question No's. 8, 9 & 10, with the reason to gain a deeper understanding of participating student's previous mathematical experiences and their current level of interest in craft calculations in general. The responses to this question are shown graphically below.



Encouraging responses here again suggested that it is almost never a lack of interest that has disheartened students previously. The responses here tie back into the previous three questions and also reflect findings emerging from the literature review.

Question No. 12; *do you feel that your current understanding of applied trade mathematical calculations could hold you back in your future career*; this question probes for answers as to the students perspective on their future career and how they feel that craft mathematics may play a part in that. The responses to this question are shown graphically below.

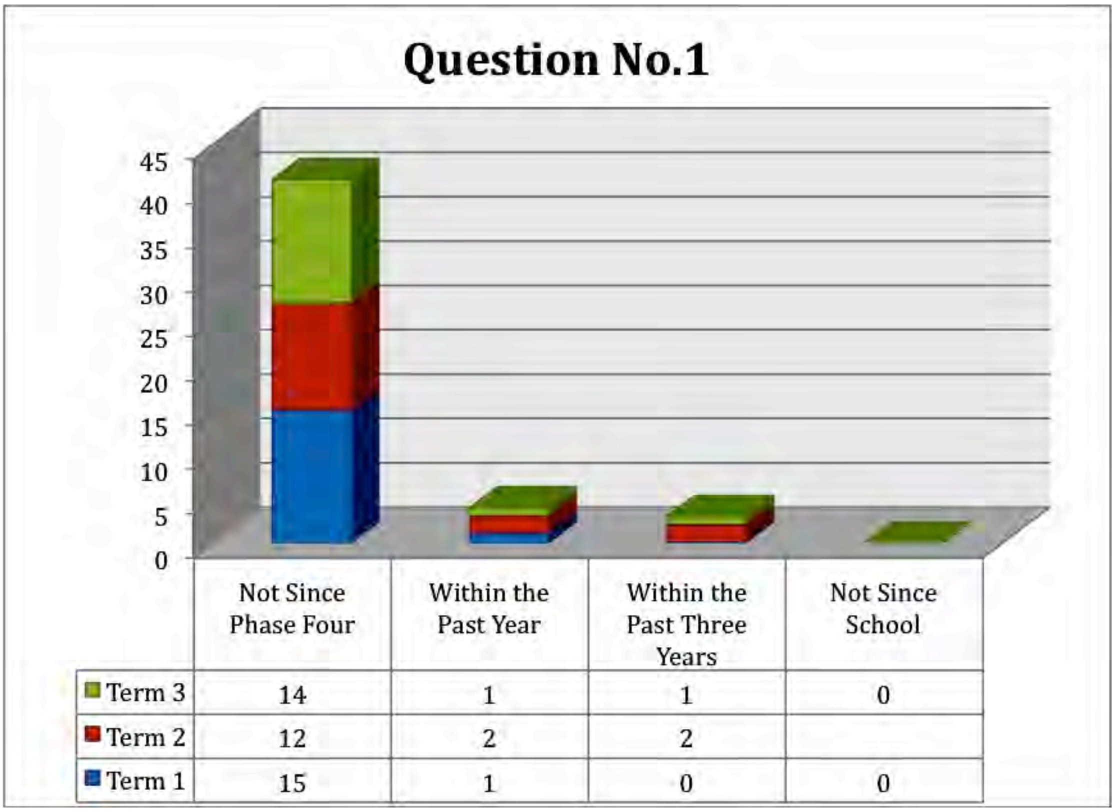


The start of term questionnaire suggested that although many of the students did not enjoy their past experiences of learning mathematics, most had no fear of learning and were willing to learn more about the calculations used in their craft. The students' responses also suggest that the methods used to teach mathematics in the past had an impact on their level of understanding of the subject. This in turn appears to have led to many students being unable to apply trade calculations to real working situations. There was also a mixed opinion on whether their knowledge of applied trade calculations could hold them back in their career. Later focus group discussions implied that those who initially answered 'no' to this question were unaware of how easily and usefully applied calculations can be integrated into their craft.

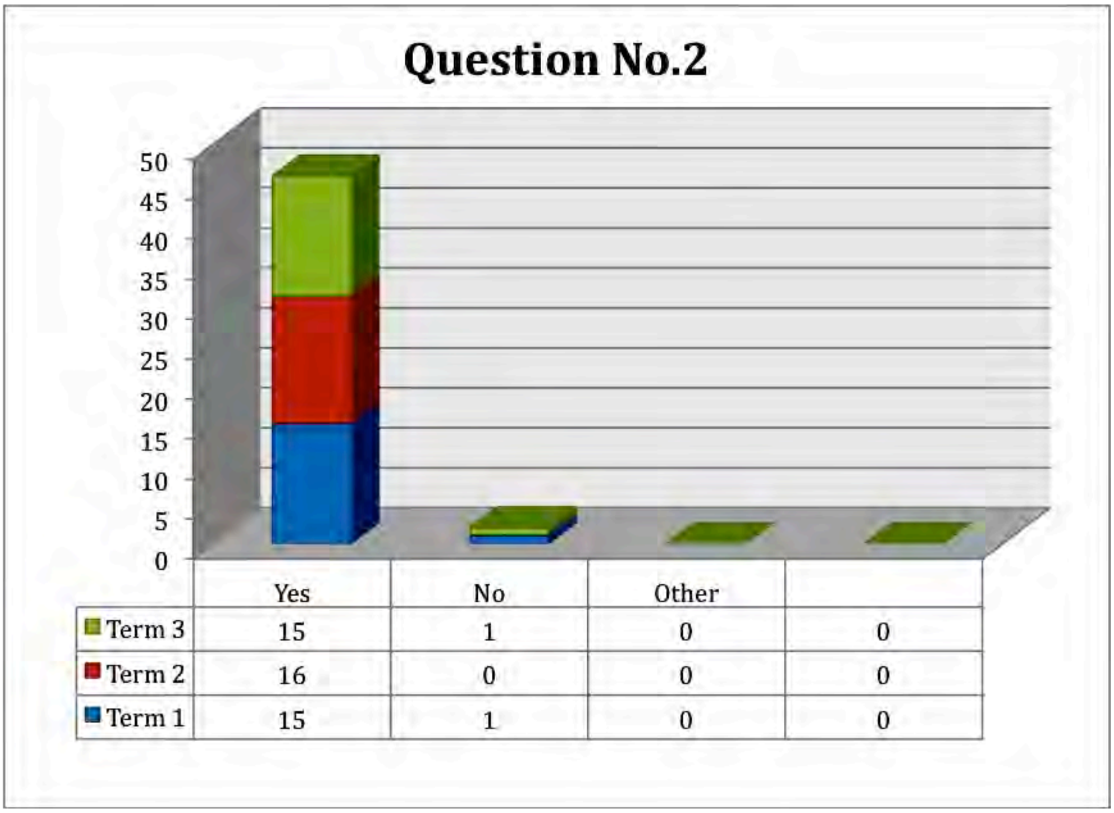
End-of-Term Student Questionnaires (Cycles 1, 2 & 3):

This end of term questionnaire was issued ten weeks after the initial set of questions. Whilst linking to the initial questionnaire, this was also used as a reflective look back over the course as a whole.

Question No. 1; *before this Project-Based Learning course when have you last studied any calculations or mathematics*; this question links back to question No. 1 in the initial questionnaire.

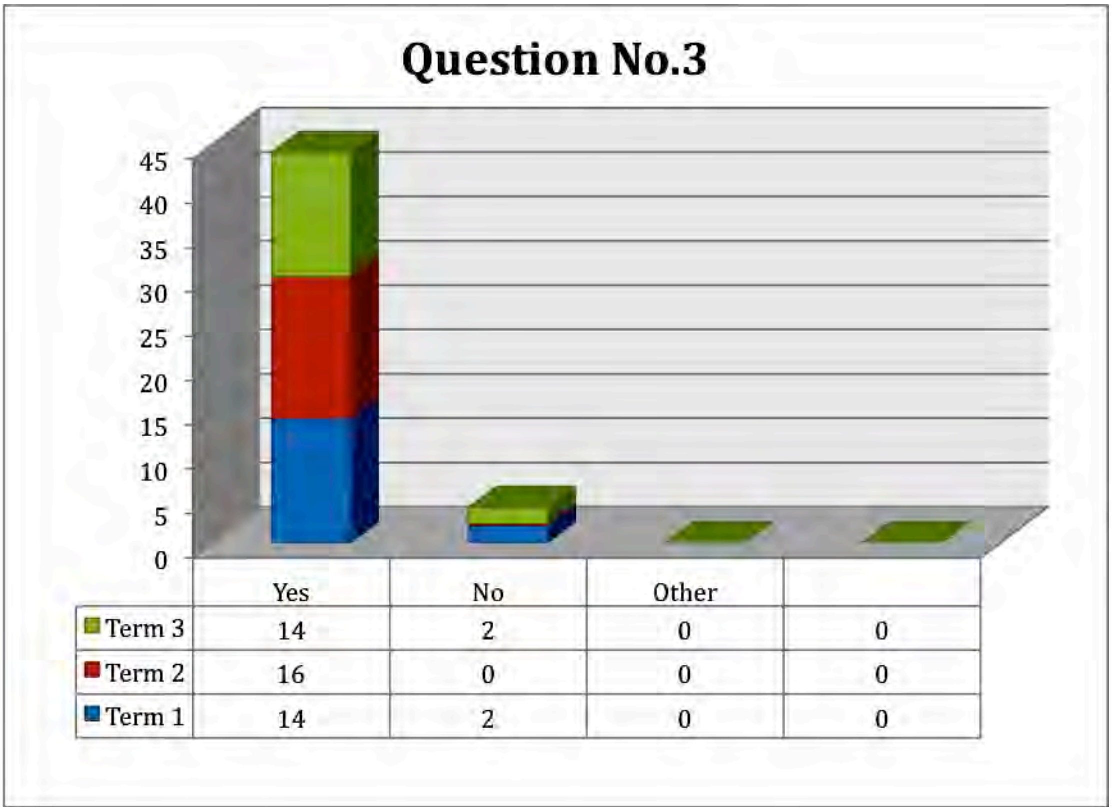


Question No. 2; *having done this course do you now feel more confident about using trade calculations*; this question while linking back to question No. 9 in the initial questionnaire also seeks to find out if students would be now more likely to use craft calculations in the future.



With project-based learning providing an end product and being directly related to real-world plumbing situations, students' confidence level with applying or using trade calculations appears to have increased. This was further explored within the focus group sessions and observational reflections.

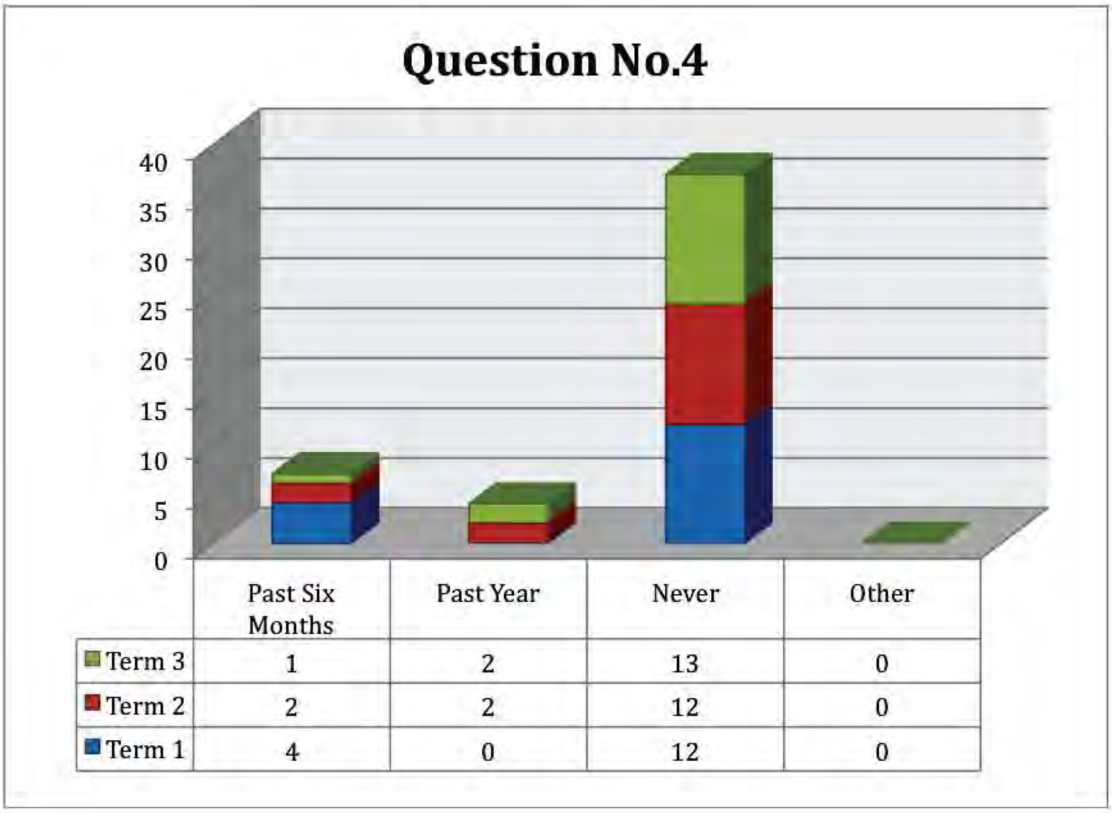
Question No. 3; *would you consider your current understanding of mathematics has improved since doing this course*; this question while linking back to question No's. 3, 11, & 12 in the initial questionnaire also seeks to establish the effect that PBL may be having with these students.



	Yes	No	Other	
Term 3	14	2	0	0
Term 2	16	0	0	0
Term 1	14	2	0	0

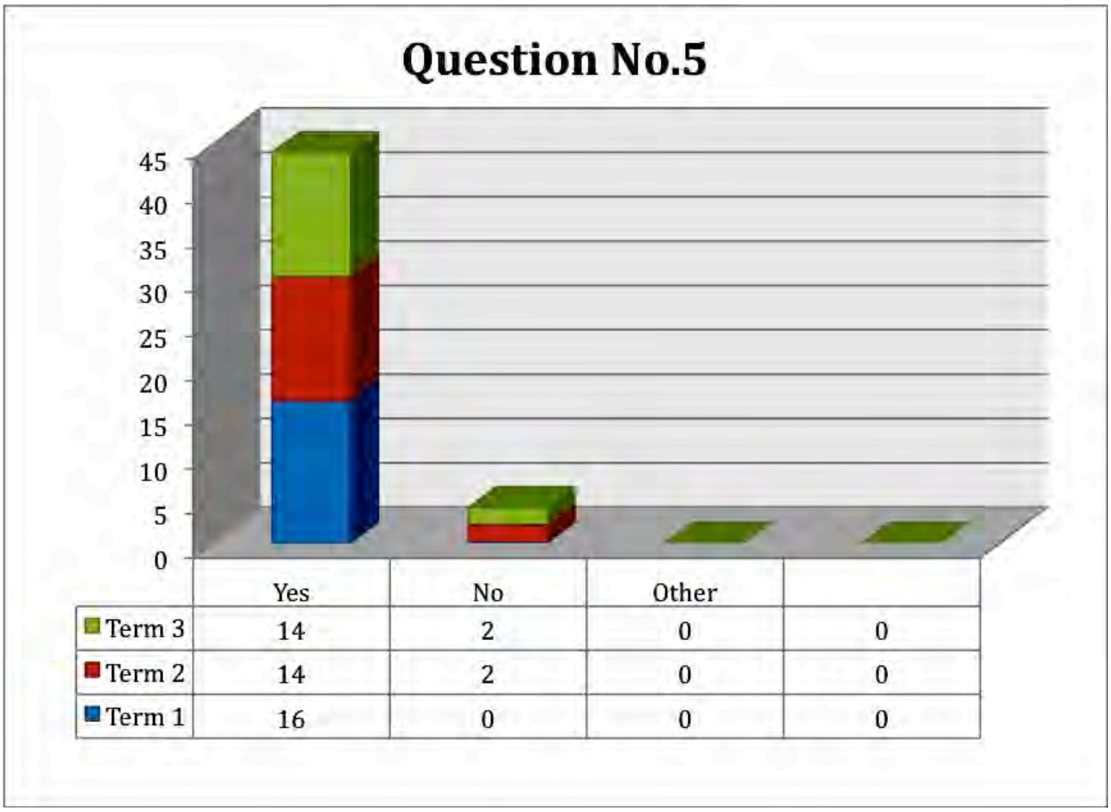
With few exceptions the respondents to this question have reported an increase in their understanding of mathematics in each of the three terms of the research period. Focus group interviews and observational research later indicate that most participants put this down to their experience of working on applied mathematical craft tasks through the use of PBL.

Question No. 4; *when have you last used any mathematical calculations in your line of work*; this question while linking back to question No. 4 in the initial questionnaire is also used as a lead into the next question.



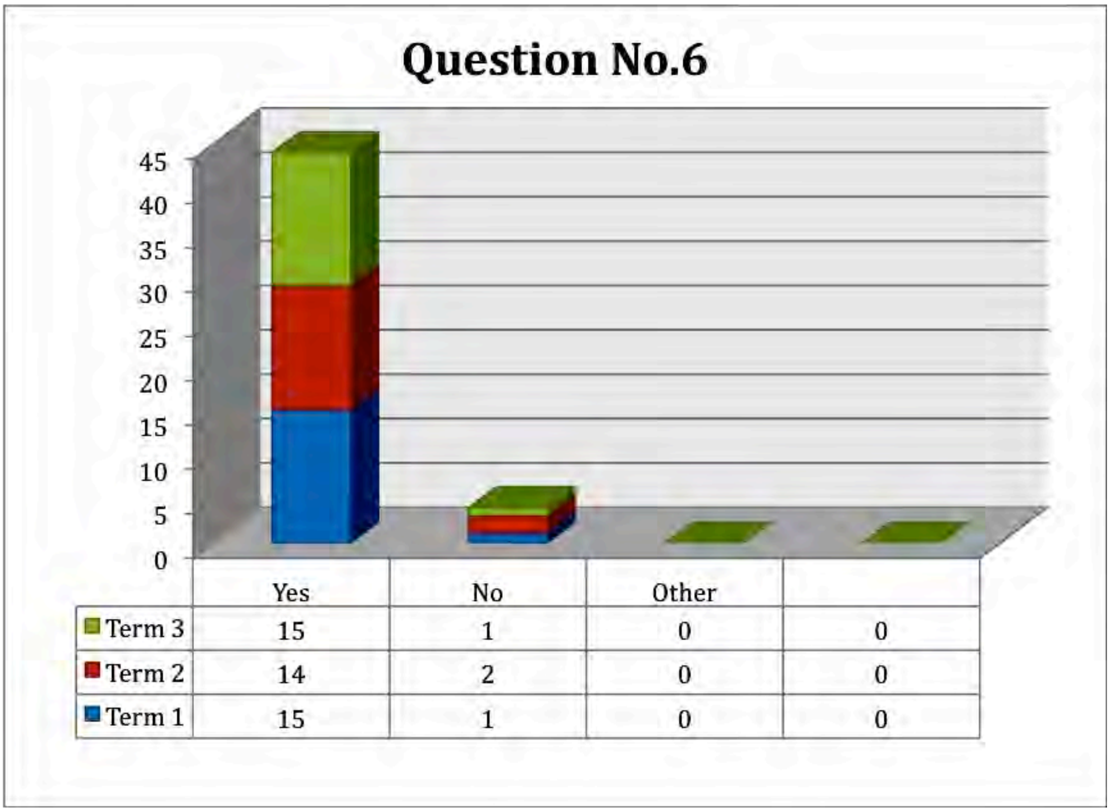
	Past Six Months	Past Year	Never	Other
Term 3	1	2	13	0
Term 2	2	2	12	0
Term 1	4	0	12	0

Question No. 5; *would you now feel confident about using maths in your line of work*; this question while linking back to the above and also to question No. 9 in the initial questionnaire is included to establish the effect that PBL may be having with these students.



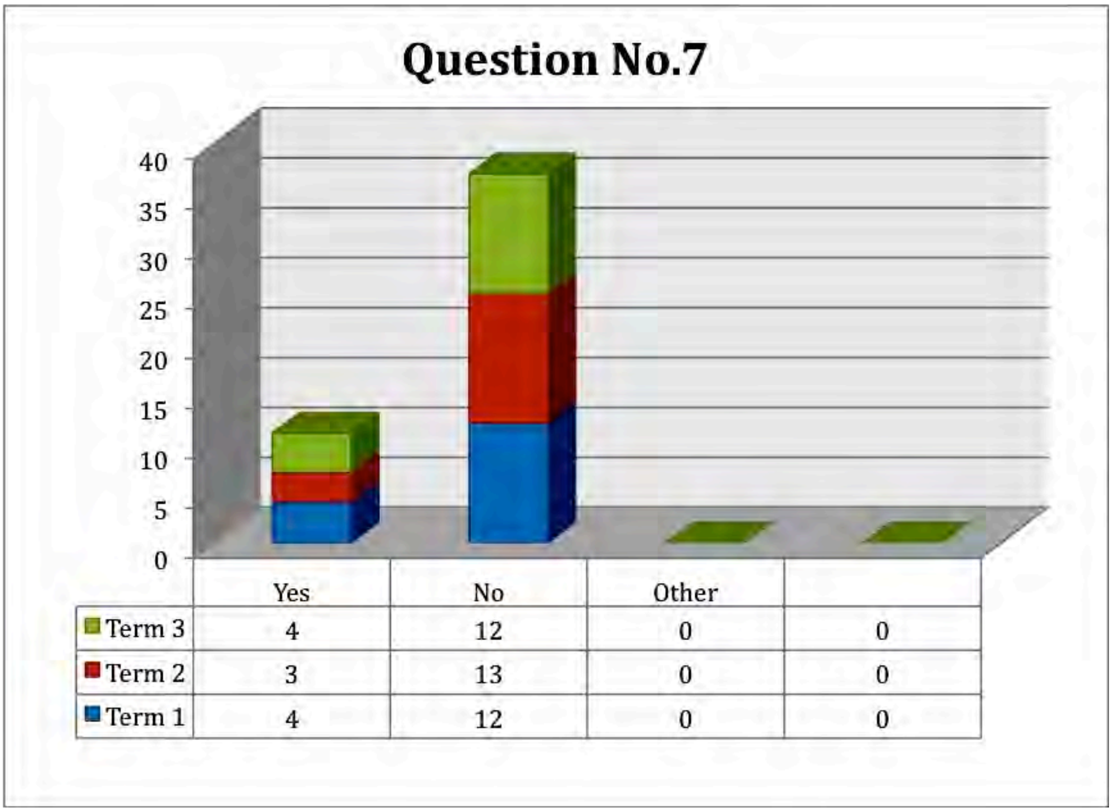
With few exceptions and with project-based learning providing an end product and being directly related to real-world plumbing situations, students confidence levels with applying or using trade calculations appears to have increased. Where question No. 9 in the initial questionnaire showed sixteen students were fearful of learning mathematics, confidence in their own abilities appears now to have increased over the duration of the course. This was also explored within the focus group sessions and observational reflections.

Question No. 6; *would you now like to know some more about the mathematics and calculations used in your trade*; this question was used to establish the effect that PBL may be having with these students and gauge their confidence levels with using applied calculations and willingness to learn more.



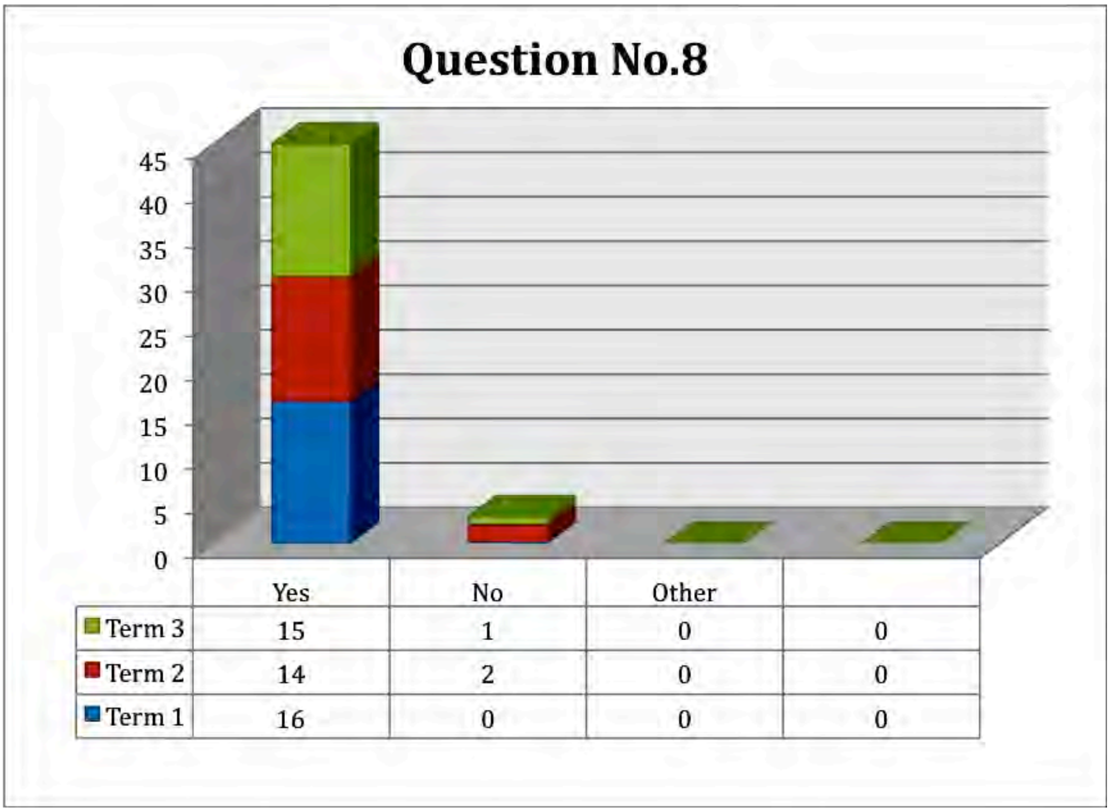
This question links back to question No. 6 in the initial questionnaire where respondents showed a willingness to learn. While the initial questionnaire 'yes' response was high there was now a slight improvement on that. I have found through observational records and interviews that these students are very willing to learn, but they need to see a relationship to their chosen craft and a reason for acquiring these skills.

Question No. 7; *have you ever used mathematical calculations to design any part of a heating or plumbing system*; this question links back to question No. 7 in the initial questionnaire and also as a lead into the next question.



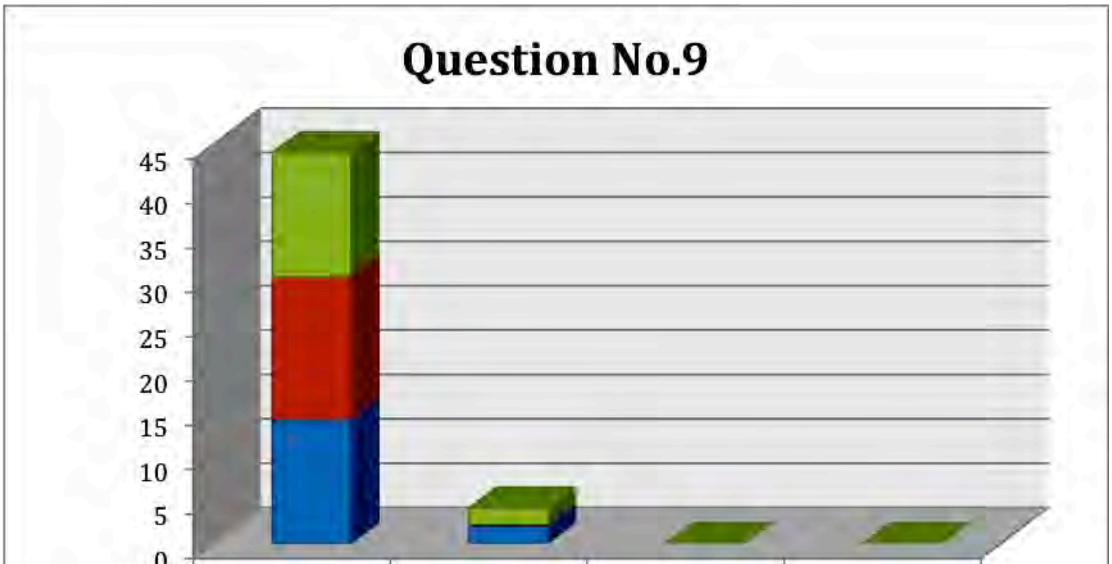
	Yes	No	Other	
Term 3	4	12	0	0
Term 2	3	13	0	0
Term 1	4	12	0	0

Question No. 8; *would you now feel that you could use some calculations to design part of a heating or plumbing system*; this question was used again to establish the effect that PBL may be having with these students and also to gauge their knowledge and level of confidence with using applied calculations after participating in the course.



The contrast between the previous two questions suggests that most of these students now feel more confident in their knowledge to be able to apply their mathematical skills into some design work. This was also explored within focus group interviews.

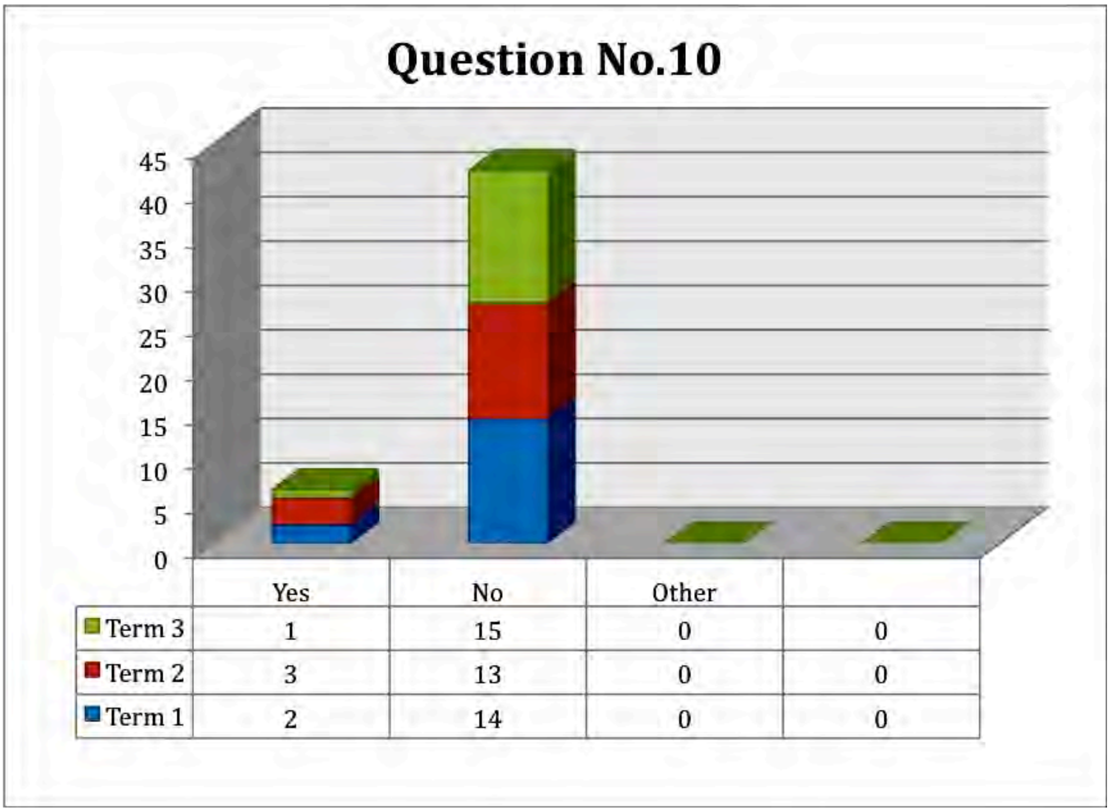
Question No. 9; *have you enjoyed learning mathematics in this course*; this question while linking back to questions 8, 10, & 11 in the initial questionnaire also seeks to establish the affect that PBL may be having on these students and the level of interaction that took place with their peers and the topic.



	Yes	No	Other	
Term 3	14	2	0	0
Term 2	16	0	0	0
Term 1	14	2	0	0

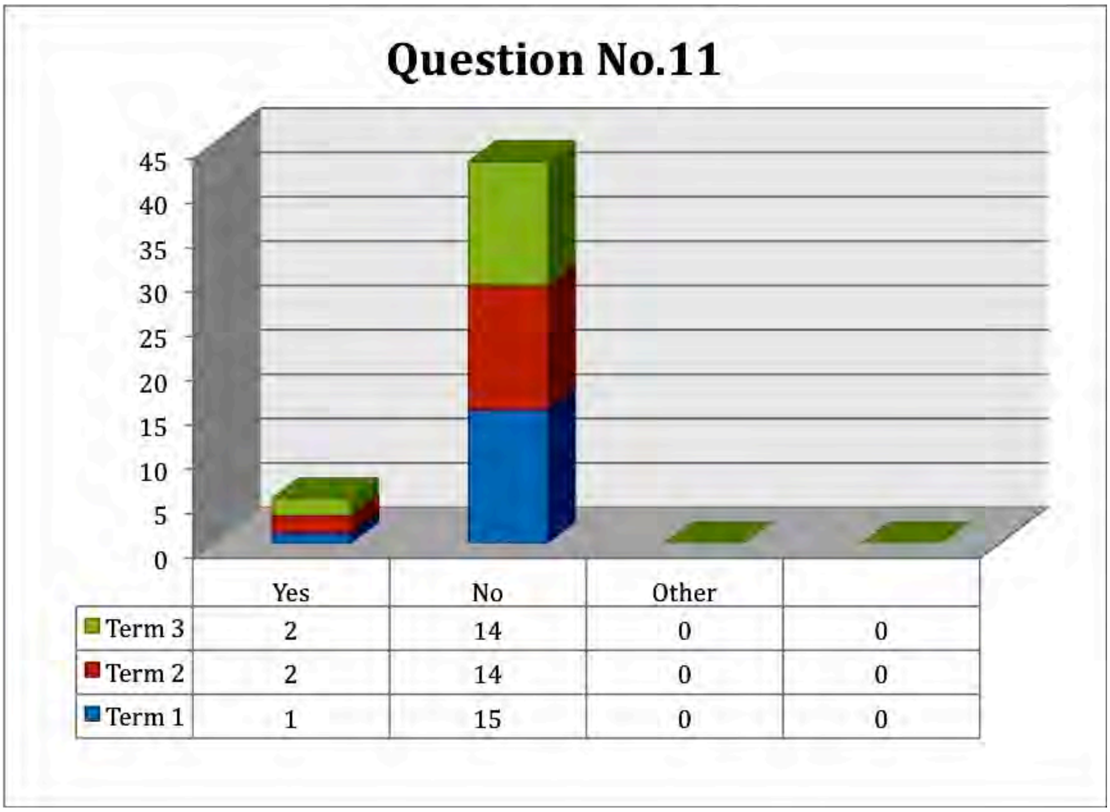
While the response to this question was quite encouraging, observational and focus group records further presented in this chapter also show a high level of engagement in and enjoyment of this type of learning.

Question No. 10; *have you any fear of learning mathematics*; this question while linking back to question No. 9 in the initial questionnaire also seeks to establish if the interaction with PBL has improved the confidence levels of students to learn mathematics.



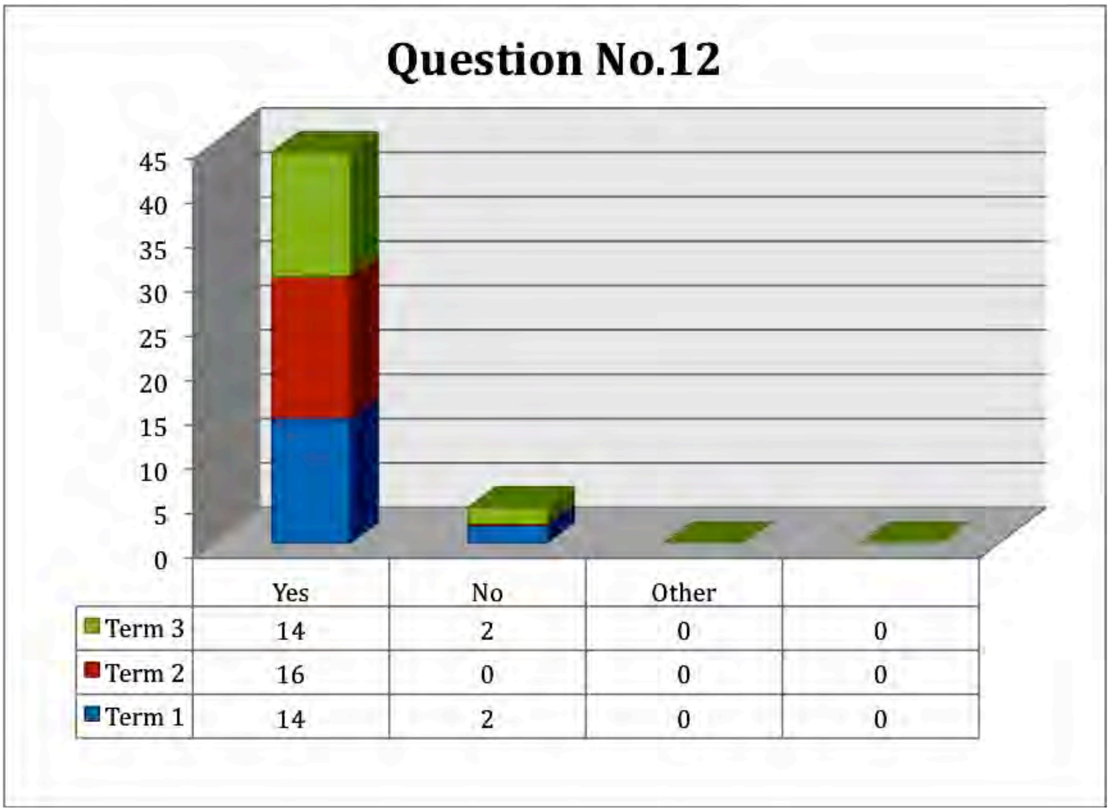
Each group's response to this question has reported a decrease from the initial questionnaire in the level of fear experienced while learning maths. Further reflective observations show that with PBL students are encouraged to come up with their own ways of solving problems and subsequently show higher self-confidence in their personal mathematical abilities.

Question No. 11; *would you rather if mathematical calculations were not included in this course?*; this question while linking back to question 10 in the initial questionnaire also seeks out any changes in opinions from start to finish of term.



While the willingness to learn mathematics was high at the start of each term, there is also less of an opinion to remove mathematics from the course having gone through the it using PBL.

Question No. 12; *do you think the way applied mathematics were taught to you in this course was any better or easier than your previous experiences*; this question was included to get an idea of the reaction to PBL used to teach applied mathematics and calculations.



	Yes	No	Other	
Term 3	14	2	0	0
Term 2	16	0	0	0
Term 1	14	2	0	0

A high positive response to this question together with focus group interviews suggests that these participants have had a better learning experience of applied mathematics using PBL than other methods they have encountered. Observational records also show high levels of self-directed learning taking place in the PBL classes over the course of the three terms.

Appendix 18: Qualitative Data Presentation – Cycles Two & Three

Action Research: Cycle 2: January 2010 – March 2010: Qualitative Data Presentation

Observational Research (Cycle 2):

From my observational records of cycle one I had noted that the class dynamic had changed to a noisier and more interactive environment. When the second cycle started having just finished the first eleven-week phase, this noisier atmosphere now seemed normal practice to me. However, I had to be aware that this was now a new type of learning and teaching environment for this new cohort. As observed in cycle one, the new group of participants also took to this type of learning quite quickly and from the outset there was much interaction, enthusiasm and discussion between students. This also allowed me to communicate one-to-one with learners experiencing difficulties.

My observational records from cycle two reflect those of the first cycle with regard to the interest and willingness of the participating students to learn. I have observed that their interest levels are stimulated when the projects that they are working on have a direct link to their craft, and also produce a useable and practical end result. Many comments referred to the fact that they could now understand the meaning of the calculations that they were unable to identify with during previous experiences.

The projects issued to students for the second cycle had the same mathematical content from the curriculum as before, but with the exclusion of the sectional and elevation aspects of the drawings. This was an intervention that was thought appropriate from cycle one as discussed in section 4.4.2 above. In a comparison of observational records from cycles one and two there appears to be less confusion with the interpretation of the project design drawings since this intervention. A note from my observational diary also suggests that the reading and interpretation of both architectural, structural, and building services design drawings should possibly form part of the plumbing apprenticeship curriculum.

The questions and tasks in the project for cycle two were designed to simulate many typical plumbing scenarios and also reflect typical examination questions from past papers. This was also an intervention thought appropriate from cycle one as discussed in section 4.4.2 above. From my observational diary I have recorded that;

> As with cycle one this is a much busier classroom environment than previous mathematical classes I have experienced. The interest levels appear much higher and interaction between students seems more meaningful. There are genuine mathematical applications being tested here in various ways to reach a practical conclusion to the problems and tasks incorporated within the projects. Students are concentrating on a single task and staying with it until it is completed. The mathematical interaction that I am having with students, when required, is of a much higher level than I have experienced in the past. There also appears to be a deep level of learning with understanding taking place within the group. This is evident through the level of questions being asked of one another and of me as facilitator. As previously recorded these project-based classes appear to go much quicker than any other classes that I have throughout the week. (Observational diary 24th February 2010)

An observational record from the following week reflects upon the enjoyment that many of the students appear to be having in comparing and debating the results of their plumbing design calculations. Some of these students even took it upon themselves to incorporate further design calculations into their project. These designs ranged from sizing solar panels to calculating the domestic boiler power required if combined with a modern heat pump. "*I can now clearly see the use for these calculations, it's another skill that I can now use*", were typical of some of the anecdotal classroom comments that have been recorded in my observational diary from cycle two.

The additional design work that some of the students did on their design projects was done in their own time and presented in the classroom for discussion. In my experience, this interest in applied plumbing calculations and design work has rarely occurred at this level. "*Why can't all subjects be taught this way*", is a comment that I have recorded many times over the period of the first two phases of this research project.

A further observational record notes that;

> These students have shifted their emphasis away from comparing mathematical answers to discussions of how they arrived at the end result or product. They are more interested in exploring the logical process used to arrive at a solution to a task rather than the end figure. It is interesting to watch different approaches and learning styles producing the same results. I have interpreted this as showing a deeper understanding of the mathematical process used to achieve a result rather than on the result itself. These students show a keen willingness to provide feedback to their peers, and to me as facilitator, on their levels of understanding of the various project tasks. This activity is showing itself capable of accommodating many different learning techniques. (Observational diary 10th March 2010)

My observational diary records from the second cycle of this action research project generally reflect that the interventions have proved worthwhile. There appeared to be a less confusing start for the students along with higher interest levels nearer the end of term with the incorporated examination type questions. The experience gained from the first cycle of the research along with positive results and feedback, also added to my own confidence in running this type of teaching and learning paradigm for the second phase.

Reflective Diary (Cycle 2):

As mentioned above the diary was used for the purpose of recording interventions that I thought might be appropriate to introduce into the next cycle of the action research process. It was also used to reflect upon my own learning experiences throughout the research process and also record and monitor any ethical issues.

Having gone through cycles one and two of the research along with cross-reference to my observational diary, questionnaires and focus groups I felt that some further interventions were necessary for cycle three. During focus group interviews and classroom discussions, most participants agreed that the other subjects I was covering with them could also be incorporated into the design project. It was suggested that an even deeper understanding of the mathematical aspect of that particular subject could be achieved along with a better comprehension of the subject itself. These types of comments have also been frequently recorded in my observational diary. With reference to this it was decided to incorporate some design work from another subject (Low Pressure Hot Water Heating) into the project for cycle three. This again reflects and covers the content of the FÁS curriculum for that subject and the related applied calculations. The project calculations and drawings incorporated into cycle two of the research were well received and also maintained high interest levels throughout the term. Because of this no further interventions to this aspect of the research was thought necessary for cycle three.

From a personal learning aspect this reflective diary has enabled me to record my own feelings during cycle two and also form a self-evaluation account of the experience. As with any positive experiences, one tends to gain confidence in a system that yields encouraging results. As cycle one of this research project had met most of my expectations, I recorded that, amongst the initial concerns of undertaking an action research project, is that results may turn out unfavourably for the participants concerned. Thoughts of 'what if this does not work' does little to encourage one to undertake an action research project especially with students who are under pressure to complete a very intense eleven-week programme and associated examinations. However, with such positive levels of feedback from participants of the research project after cycle one, there was much relief along with higher confidence levels going into cycle two.

From my reflective notes the data suggests that although there were some further interventions thought necessary for cycle three, the main aims relating to the implementation of a PBL approach appeared to have been achieved in cycles one and two. Data from observational diaries, classroom discussions and focus groups all suggest that the students found this type of learning both challenging and enjoyable.

From a teaching perspective I was still much busier in class as a facilitator and also outside of contact time, in the compilation of the project-work. However, I have also found the PBL classes far more productive than other classes that I teach, and often I too could learn from students who are sometimes very innovative in their design work. No ethical issues arose during cycle two of the research, but continual monitoring of this was essential for good research standards to be maintained.

Focus Group Interview (Cycle 2):

The second focus group interview was held in a classroom familiar to the students in D.I.T Linen Hall on 12th March 2010. There were six student participants present at this interview. This particular focus group interview lasted one hour and ten minutes using a set of pre-prepared questions to prompt the discussions. Participants were again chosen from those whom I believed would express their feelings freely and who would also represent a cross-section of the whole participating group. The age profile of this group ranged from 18 to 25.

As this was the second cycle of the research process the pre-prepared questions were designed not only to link with the questionnaires, but also used to bring forward thoughts on observations on the interventions made during cycle two. As with the focus group session from cycle one however, there was no strict pattern as to which direction the discussion might proceed. From cycle one I had found that the participants were more than willing to express their feelings and thoughts in a very open and honest manner. They appeared confident among their peers to express themselves well and were also comfortable in the casual style of conversation and the familiarity of the surrounding environment. From the cycle one focus group experience I gained added confidence to probe a bit deeper into the thoughts of participants for the cycle two focus group interview. This meant focusing further on past experiences of learning mathematics from second to third level education and comparing these thoughts and comments to those of others found within the literature review chapter of the research project. As with the first focus group interview, this group expressed strong opinions and feelings on the learning and teaching of other subjects in their trade and ideas they thought may improve this experience.

Even though various research methods were used for verification in cycle one, it was not until cycle two of the research concluded that a more complete picture began to emerge. Now a comparison of the data from all of the research methods could be made but with the added depth and breadth of information emerging from two separate groups of individuals. Over the first two cycles of the research project, I have found the focus group sessions along with the observational data to be rich in content and very relative to the subject matter. In both situations, students spoke freely about their thoughts on applied calculations and mathematics, their previous educational experiences and their current feelings on PBL. A discussion of the findings from this focus group interview and all other research methods used in cycle two are included below.

Action Research: Cycle 2: Discussion of the Research Findings

Through focus group interview data and classroom discussion many of the research participants reported that they have found traditional mathematical lecturers an ineffective method of learning and teaching. They also expressed similar motivational problems with other subjects and often found it difficult to link theory with practice. Many participants expressed disappointment at not being able to link all of the craft subjects together into one project to get a clear understanding of their relationship. From the cycle two focus group, participant E commented; *"each subject is being covered by a different lecturer and in a different manner with no linking to each other"*. Most participants were in strong agreement with this and comments followed such as, participant A; *"I know about the various subjects in my trade but I can never see where they would all come together, they have always been taught separate from one another"*. Participant B; *"it would be better if we could use a project like the one we used for mathematics to put all the services together, we would learn much more about our trade"*.

In similar comparison to group one of the research, and from data collected from cycle two, it is evident that most of the participants chose not to study or use any form of craft related mathematics after phase four of their apprenticeship education and training. Even where the majority of participants held a Leaving Certificate and were willing to learn trade calculations, many displayed no motivation to do so. Since phase four of their apprenticeship most participants had not used any calculations in their line of work with many expressing doubt as to their ability to know what calculations to use for a given problem.

Many of the research participants also reported that they simply could not remember any of the mathematical formulas shortly after leaving phase four as they had only tried to memorise them for examination purposes. "*We were given formulas and questions that we were told to learn for the exam but I couldn't see how they applied to plumbing*" were typical of comments made in focus group sessions. Participant C also commented that, "*I want to learn about my trade and want to open my own business but mathematics and other subjects are taught in a very impractical way to cover an exam, and not in a way that would improve you as a tradesperson*". Participant F further commented that, "*we just did question after question, it was so boring but we had to do it for the exam, but we never knew where they would be used on site*". From data collected through observational and reflective diaries, questionnaires and focus groups along with classroom discussions over two cycles with different groups, it is evident that with very few exceptions, these students are more than willing to learn about their craft.

When given tasks that are related to the craft that they have chosen to pursue, most engage with enthusiasm and with a high level of motivation. "*Mathematics are far more worthwhile when done this way (PBL), at least now we can see where they can be used in our line of work*" was a comment that was expressed by many participants in both cycle one and two focus group interviews.

An analysis of the data from the start of cycles one and two shows mixed feelings between research participants in relation to the importance of trade mathematics. However, a thorough analysis of the data collected over the term of both cycles strongly suggests that the introduction of PBL has much improved the confidence levels, understanding and appreciation of applied calculations and mathematics. Emerging information synthesised from both cycles of the action research strongly suggests that having gone through the PBL course, participants are now treating their knowledge of applied calculations as "*another skill*" that they can now exercise on-site. Participant A also remarked that, "*we are in here to learn about our trade and then use what we have learned in work, it's actually embarrassing when my boss has* *asked me to do something and I don't know how, he thinks it's my fault. He wonders what I have been doing in here for the past three months. But we were never shown how calculations and a lot of the other subjects could be put into practice. At least now I really understand how these calculations can be used in my job".*

During the course of this research, and contrary to comments that are sometimes made of students, I have found that most of the participating students over the course of the first two cycles have shown a distinct willingness and interest to learn along with high motivational levels during the PBL classes. Comments relating to the use of PBL ranged from, *"If I thought that a course was going to be taught this way I would like to go on to further education"*, to *"I actually looked forward to coming into this class, I thought that I would never say that about mathematics"*. It appears that when these students are given a challenging task that is real-life or work related, they engage willingly with it, exploring different avenues to reach a successful outcome. This is evident in class where meaningful discussions related to the tasks in hand can be observed. Student B also remarked that, *"I can now see where applied calculations are an essential part of my trade and I can now use them easily"*.

Negative comments made by students in cycle one in relation to summative assessment were often repeated with the second group in cycle two of the research. As mentioned above and discussed in the findings from cycle one there is strong evidence emerging from the various forms of data to suggest that these students really want to learn about their trade. Most students from each group expressed concerns regarding the 'rote-type' learning encouraged by the use of these summative assessments. Many expressed views of not being able to apply the content of most subjects to their trade with comments like student F, *"after the test all the theory is just useless information that we don't know what to do with"*. Reasons given for this related to the vast amount of content within the curriculum, as discussed in detail in Chapter One, along with the didactical learning and teaching methods usually employed to deliver it. As with the first group of students this second cohort also reported that they felt their craft knowledge was not increasing sufficiently over the eleven-week period of this off-the-job phase of their apprenticeship. Student B, summed up the feelings of the group with, *"it would be so much better if we were given a project drawing in week one and told that we had to design all of the* *mechanical services into it by week nine or ten. We could even do this in pairs and we would learn so much more about our trade"*. Student A followed this comment with, *"we found the mathematics really interesting this way (PBL) so imagine how much we could learn if other subjects were done and assessed this way"*. Student E also added that, *"we would be better plumbers if we could do a project like that, twenty questions in an exam does not really show your potential as a craftsperson, it's just a test of memory"*.

The information gathered from the cycle two data of the research process corresponds to findings from cycle one and the literature review in relation to apprentices' progression to further education. Some of the students had thoughts of progressing to other craft related courses but very few suggested a return to full or part-time further educational courses. However, some students suggested that if courses were taught using PBL they would be more inclined to consider a move into further education.

From the data gathered and analysed over the second eleven-week research cycle, I felt that most of the aims and objectives as outlined and discussed in section 1.4 had continued to be met. The general attitude towards learning among this group of students remained very high throughout the term. Among the contributing factors were feelings of doing something worthwhile and interesting that could be used in their future career. As with the first group of participants, I have found that the students appear very willing to learn for themselves and from each other in a meaningful manner and apply their knowledge to a practical design project. Most of the students in this second group also indicated that they felt they had met the learning outcomes discussed at the start of the term. A conclusive discussion of all three cycles of this action research project is included in Chapter Five.

Action Research: Cycle 3: March 2010 – June 2010: Qualitative Data Presentation

Observational Research (Cycle 3):

Observational records from the previous two cycles of the research reported a change in classroom dynamics to a more interactive and noisier environment. My observational diary from the first class of cycle three also reports an immediate change of atmosphere and attitude within the final group of participants. With this group I had decided to run my other subjects in the traditional lecture type manner for the first two weeks in order to obtain an idea of their level of interactional activity. During these first two weeks interaction from this group was at times lively but for the most part any feedback had to be encouraged or teased out in the form of questioning from me. With the introduction of PBL in the third week however, things changed almost immediately. My observational record of that day reports;

> There was an obvious change of atmosphere in the class today. Students shifted about in seats getting themselves ready to tackle the first stage of the project they had just received. It resembled a group getting ready to engage in some physical work activity. Having read the initial project brief there was much interest in the content and many questions followed to clarify some points. The first hour or so has previously proved to be the busiest time for me as I have to engage quite a lot on a one-to-one basis with some students and also with the whole group as queries arise. It is then quite interesting to watch as these students gradually take control of their own learning both individually and in consultation with their peers. They seem like a different group than I have had for the past two weeks. Some students who had expressed dislike for mathematics also made good personal learning progress today. (Observational diary 14th April 2010)

Again I had to be aware that although this was now my third cycle using PBL, it was a new method of learning for most of this group. For this reason I again found it important to work very closely with the whole group for the first class and then more with certain individuals when required for the remainder of the term. I have found over the past year that although I find myself busier as a teacher both inside and outside the classroom using PBL, I still have more time to interact on a one-to-one basis with students when required. This is because most of the time the other students are busy self-learning through their project work. As with the previous two groups, these participants took to this learning and teaching technique very quickly and displayed high levels of interaction and enthusiasm in their learning.

Many of the comments relating to this form of learning expressed a new understanding of the meaning of the calculations that they could not identify with during previous experiences. *"Ah now I see, is that why I have always had to do that?"* was one of those eureka moments for a particular student who had just seen the relationship between a calculation he had been doing since phase four and a real-life plumbing situation.

The projects issued to students for the third cycle had the same mathematical content from the curriculum as before but also incorporated some design work from another subject (LPHW Heating Systems). This was an intervention that was thought appropriate from cycle two as discussed in section 4.5.2. Notes from my observational diary suggest that this intervention added to the authenticity of the project work and seemed to be appreciated by most of the participants. Many deeper questions regarding this topic were discussed than with the previous two groups.

> The additional subject included in the project this term appears to be adding to the interest and learning levels. This is an intervention suggested by the previous group of participants and it seems now very worthwhile. However, I found this class extremely busy, as I now had to deal with in-depth queries from both subjects and the integration of these into one project. Most of the participants took to this intervention really well with many working through their break to complete the problem. Other interventions previously incorporated also continue to improve engagement levels with the research process. (Observational diary 28th April 2010)

My observational diary records from the third cycle of this action research project generally reflect the interventions incorporated over all of the research cycles have proved worthwhile. Observational diary accounts and reflections from the past year generally report very busy classrooms with high levels of interactional activity and self-learning taking place. This has happened within an enjoyable atmosphere of learning and teaching, where the majority of those who took part have demonstrated a keen willingness to learn.

Reflective Diary (Cycle 3):

As this is the final cycle of the action research process there were no further interventions to be incorporated. Although constantly monitored in line with the previous two cycles, no ethical issues arose that required any action during this phase of the research.

From a personal learning aspect the reflective diary has enabled me to record my own feelings during each cycle of the action research and also form a self-evaluation account of the experience. As with the previous two cycles I have found PBL to be a most satisfying classroom experience for both the students and myself. I have felt that I no longer need to 'force' the learning through lectures. Instead students now come looking for the information for their own needs. This in turn presented challenges to myself, as I was no longer in charge of the proceedings I needed to be well prepared for some deep levels of enquiry from students. This I really enjoyed and it also reminded me how much one needs to know about their subject matter in order to teach it using PBL. Students also come to realise this during PBL, as they are very engaged in learning from one another. My reflective diary also recorded a high level of learning on my own part from many innovative ways that students chose to overcome the tasks at hand. It was also interesting to observe the many different ways in which students learn. For applied mathematical problems some chose to sketch or draw out the various systems they were working on while others discussed the problem and then chose their own favoured route. I too learned a lot during this process to the extent that I could use some of these students' ideas on learning, to teach other classes.

Reflectively, I have found that the main aims relating to the implementation of a PBL approach appear to have been achieved in cycles one, two and three of the research.

Focus Group Interview (Cycle 3):

The third focus group interview was held in a classroom familiar to the students in D.I.T Linen Hall on 27th May 2010. There were six participants present at this interview. This particular focus group interview lasted one hour using a set of pre-prepared questions to prompt the discussions. Participants were again chosen from those whom I felt would express their feelings freely and who would also represent a cross-section of the whole participating group. The age profile of the group ranged from 18 to 24.

As with previous focus group sessions this interview did not follow a strict pattern and was loosely guided by the prepared questions. However, the interview process allows views that were expressed in the questionnaires to be elaborated upon along with any ideas or feelings for improvement from participants. I have found over the past year that most of the students involved in the research are very willing to give an honest opinion on PBL and their own learning in general. With few exceptions the students have demonstrated a high level of interest in their craft and are willing to endeavour to improve their knowledge within it. These focus groups have given the participating students the scope to voice their opinions on learning, not only applied calculations, but also about their craft in general. It is interesting to note how many of the comments made during interviews over the past year reflect the findings that surfaced during the literature review search. This is further discussed in Chapter Five below.

Action Research: Cycle 3: Discussion of the Research Findings

From all of the data collected from the various research methods the picture seemed to emerge a little clearer after each cycle of this action research project. It appears obvious to me now that the majority of student apprentices have a desire to learn about their chosen craft and will engage fully in tasks that are seen as relative and worthwhile. Within the research project, this has included applied calculations and mathematics, a subject that in the past I have found difficult to get students to fully take hold of. Yet with very few exceptions over the course of the research, most of the students from each group reported quite favourably on the type of learning and teaching used in PBL. There was also much enthusiasm shown in favour of the projects with the content being so realistic and relative to their trade.

During focus group interviews, comments were expressed regarding the learning of mathematics from Junior and Leaving Certificate to Craft Apprenticeship. These included; *"I left school after the Junior Certificate because I thought I could not do the Leaving Certificate mathematics, yet now I feel that I am good at these" (mathematics)*. Participant C further commented on this; *"I did the Leaving Certificate and was good at doing mathematics while I was there, but I forgot them shortly after the exam as I could see no use for them"*. While participant F further followed; *"I also found this with the mathematics in phase two and four, I could do the calculations from the board but I didn't know why I was doing them or where they fitted into plumbing on-site"*. Similar comments to this have been recorded throughout the whole research process. On the use of PBL, this group were very forthright in their opinions. From questionnaires, interviews and observations there was favourable opinion expressed from most participants.

The data collected over the three cycles revealed that the majority of the apprentices who participated in the research held a Leaving Certificate. It has been my experience in teaching, and concurrent with the literature, that even after attaining the highest second level qualification, many students still struggle with applied craft calculations and mathematics. The questionnaires at the start of term also indicate that most students describe their mathematical abilities as only average. From the various research methods employed in this project some interesting views emerged in relation to this. Strong feelings were expressed within classroom discussions and in focus group interviews relative to second level mathematical educational experiences. Participant F, *"it was just formula after formula we had to remember, I could do them but I had no idea what they were about, I still don't, I cant remember them any more anyhow"*. It appears that the mathematical detachment from anything relating to real world problems is one of the reasons why many students struggle to understand or fully engage with mathematics.

Many of these students have then faced similar problems during phases two and four of their apprenticeship. It was therefore refreshing during classroom observation to see students having fun with mathematics, along with a clear understanding of why they were doing them. Participant C, *"I have enjoyed maths in this phase, I was ok at them in school but I didn't like doing them"*. Participant E, *"this is the first time that I liked doing mathematics, I thought that I was useless at them but I'm not that bad now"*. Summing up the general feeling on this, participant F commented that, *"if there is a chance to be better at our trade most of us will try to learn, but when we can't see any use for something it seems just like the Leaving Cert again, what's the point?"*

It was also interesting to note most of the students indicated that they had no fear of learning mathematics at the start of term, and even less near the end. Focus groups further revealed that it was the fear of being asked questions they could not answer in front of their peers that often made them fearful of mathematics. Many participants attributed this to the teaching methods they had experienced in the past where generally only one style of learning could be accommodated in class. Participant A, reflected the feelings of the group; *"we were only told one way to do mathematics and if you couldn't do them that way, well that was it"*. Participant E further added; *"at least this way (PBL) you can find different ways to do the calculations and also compare and learn from each other"*.

As each of the focus group interviews over the three cycles were held at the end of term, it gave participating students a chance to reflect on their learning since first starting the course. End of term questionnaires were also used to capture this experience. As with the previous two cycles, the most negative of comments related to summative assessment. Other negative comments related to the teaching and learning methods used to deliver the curriculum having now being exposed to a different method. Concurrent with views expressed in Chapter One of this research project, all of the data collected over the three cycles of this research points to a curriculum that has so many modules, units and learning points, it is proving almost impossible to deliver or properly learn over the given timeframe.

Many students are expressing feelings of disappointment at not learning about their craft but instead are forced to memorise questions from a vast amount of material where they never see the link between them. *"We are not advancing ourselves as plumbers here, we are just memorising stuff all the time"* and *"projects from the start would be so much better to see and learn how everything fits together",* were typical of many comments made in relation to the problem. Many observations made over the whole of this research project also suggest that the studying technique being used by many phase six plumbing apprentices, is driven by memory rather than understanding. I have tested this many times during the year by interrupting students who are studying various subjects. I have then asked for a discussion on the topic they are engaged with. While being able to cite past paper questions and answers, many cannot discuss the subject holistically with other interconnected topics.

In my experience, a plumbing craftsperson needs to know the interrelationship between all building services in order to progress further in their career and accomplish a level of competence. The data collected over the course of this research projects mainly suggests otherwise.

From the data collated and analysed over the third eleven-week research cycle, it appeared that most of the aims and objectives as outlined and discussed in section 1.4 had continued to be met. The general attitude towards learning among this group of students remained very high throughout the term. Among the contributing factors was the intervention of another subject into the project-work. As with each of the previous two groups of participants, I have found that the students appear very willing to learn for themselves and from each other in a way that promotes understanding of the problem at hand. Most of the students in this third group indicated through classroom discussions and focus group interviews they had met the learning outcomes discussed at the start of the term. A conclusive discussion of all three cycles of this action research project is included in Chapter Five.