Mavromihales, Michael

Enhancing Teaching-Learning Effectiveness in Mechanical Engineering Education Through Structured Interventions and Action Learning

Enhancing Teaching-Learning Effectiveness in Mechanical Engineering Education Through Structured Interventions and Action Learning

Michael Mavromihales

A thesis submitted in partial fulfilment of the requirements for the degree of

Doctor of Philosophy

University of Huddersfield

United Kingdom

September 2019

Copyright

Abstract

Established teaching and learning methods are increasingly coming under scrutiny. This research documents the application of progressive methods of teaching and learning whilst introducing a range of disparate Action Learning (AL) delivery methods. Action Research (AR) methodology forms the basis for this work. As a means for learning, Games Base Learning (GBL) has historically been used in a range of subject areas but with limited application in Engineering and Technology. Although GBL provides a good means of motivating the learner whilst also promoting learning as fun, its effect in meeting quantifiable educational objectives remains much under-researched and therefore unknown. This research attempts to introduce GBL as part of Mechanical Engineering Education and evaluate the outcomes in both qualitative (by gauging the student learning experience) and quantitatively (by measuring changes in assessed work results as well as application). Game Based learning (GBL) activity is introduced as part of a holistic approach in supporting knowledge acquisition within a Mechanical Design undergraduate programme.

This research reports on the level of student engagement and the extent to which learning outcomes were met through the introduction of such activities as part of the case studies. Novel approaches in delivery of engineering education are presented. Frameworks and methodology are produced that can be adopted in other Higher Education Institutions for improved delivery, attainment and engagement and student achievement. Novelty in the work is also presented through the empirical data as evidence of the pedagogical benefits of educational games. This research reports on the design, development, implementation and evaluation through analysis, blended learning based on Action Research (AR) methodology.

This research bridges the gap between current and ‘traditional’ practice in teaching and learning in Mechanical Engineering Education through structured interventions in order to quantify enhanced learning experiences. Although it applies interventions to teaching and learning in the subject area of Mechanical Engineering subjects, specifically, but not exclusively, within design and manufacture. It focuses on Active Learning techniques such as Activity Based learning (ABL) and Games Based Learning (GBL) with the intention of reinforcing and applying prior underlying

theoretical fundamentals. It reviews and evaluates a selection of approaches in teaching and learning on undergraduate mechanical engineering courses.

As part of a blended learning environment, the use of Electronic Voting System for reflective learning and explorative thinking is considered. The work demonstrates how such voting systems can enhance the student learning experience by integration within a flipped classroom approach, coupled with reflective learning and experiential learning. Varied instruments of delivery and assessment along with novel methods to encourage student engagement and participation has led to improved student performance and acquisition of knowledge and skills, often with significant improvement.

Each of the approaches described as part of this research has brought unique benefits to teaching and learning fundamentals however there is evidence that combined, produce a powerful set of tools for mechanical engineering education.

Acknowledgements

The author wishes to thank Lindsey Botha, data analyst, School of Computing and Engineering, University of Huddersfield for her support in the supply and analysis of student data for case example 2. Further support, for which I am grateful for, came from data analyst Ben Hull, with whose help the researcher was able to form a profile of our undergraduate learners.

Thanks also go to Proto labs (www.protomold.eu/parts) for their supply of the resin cube puzzles used as part of the GBL activity.

Gratitude is also expressed to my colleagues Dr Krzysztof Kubiak (who has since departed from the department) and Dr Qiang Xu, School of Computing and Engineering, University of Huddersfield for their assistance in the implementation of the studio based ABL activity with various undergraduate groups and assisting in compiling the survey and assessment results, which formed the third case study.

I thank all colleagues who have shown interest in my work and encouraged me along the long road to completion. Such gratitude is especially owed to former Head of Department of Computing and Engineering at the University of Huddersfield, Professor Ian Glover and former Subject Area Leader Dr Leigh Fleming.

My greatest gratitude is owed to my valued colleague and supervisor Dr Violeta Holmes. Without your tireless guidance and encouragement, I doubt whether I would have completed this work to the point of submitting it in its current form. I look forward to continuing our research in future.

To my wife Victoria for her endless support and encouragement.

List of Publications Based On The Outcomes Of This Research

Journal publications

Case study 1 – chapter 4

Mavromihales, M., Holmes, V. (2016). Delivering manufacturing technology and workshop appreciation to engineering undergraduates using the flipped classroom approach. *International Journal of Mechanical Engineering Education*, 2016, Volume 44, Issue 2

Case study 2 – chapter 5

Mavromihales M., Holmes V., Racasan R., (2018). Game-based learning in mechanical engineering education: Case study of games-based learning application in computer aided design assembly, International Journal of Mechanical Engineering Education April 1, 2019, Volume: 47 issue: 2, page(s): 156-179

Conference presentations

International conference on Collaborative Action Research Network (CARN). Approaches to Active Learning in Mechanical Engineering Education. Bishop Grosseteste University, Lincoln 11-13 November 2016

International conference on Collaborative Action Research Network (CARN). Reporting on the outcomes of Games Based Learning in Engineering and Technology. Rethymno, Greece 20-22 October 2017

Mavromihales M. and Holmes V. (2018). 'A multi-pronged approach to blended learning; Focusing on fundamentals of mechanical engineering undergraduate education'. 3rd Annual International Conference on Engineering Education & Teaching, Athens Institute for Education and Research (ATINER), 4-7 June 2018, Athens, Greece

Contents

Figures

Tables

Glossary of Terms Used

3D MUVE – 3-Dimensional Multi-User Virtual Environments

ABET – Accreditation Board for Engineering and Technology

ABL – Activity Based Learning

AL – Active Learning

AM – Additive Manufacturing

AR – Action Research

ASEE – American Society for Engineering Education

AV – Audio Visual

CAD/CAM – Computer Aided Design and Computer Aided Manufacture

CAL – Computer Aided Learning

CATS – Credit Accumulation and Transfer Scheme

CNC – Computer Numerical Control

COTS – Commercial Off-the-shelf

CPD – Continuous Professional Development

DGBL – Digital Games Based Learning

DT – Digital Twin

EVS – Electronic Voting System(s)

FC – Flipped Classroom

FCL – Flipped Classroom Learning

FL – Flipped Learning

GAL – Game-based Action Learning

GBL – Game Based Learning

GUI – Graphical User Interface

ICEE – Integrated Concurrent Engineering Education

IET – Institution of Engineering and Technology

IL – Inverted Learning

ILO – Intended Learning Outcomes

I.Mech.E. – Institution of Mechanical Engineers

LF – Learning Factory

LLL – Lifelong Learning

LO – Learning Outcomes

MOOC – Massive Open Online Course

NAE – National Academy of Engineering

PAL – Project-based Action Learning

RAE – Royal Academy of Engineering

PAL – Project Action Learning

PBL – Problem Based Learning

RP – Rapid Prototyping

SG – Serious Games

SL – Second Life; is a 3D social software application developed by Linden Lab

STEM – Science Technology Engineering and Mathematics

TREE – Teaching and Research in Engineering in Europe

VA – Visual Aids

VLE – Virtual Learning Environment

VR – Virtual Reality

WWW – World Wide Web

Chapter 1 – Introduction

This chapter considers the motivation behind the work and the background narrative leading to it. It presents an overview to teaching and learning in engineering and technology and consequently identifies the need for ongoing engineering education research. The research is put in context by considering the work of educational philosophers and educational psychologists including Vygotsky, Bloom, Krathwohl, Anderson, Knowles, Dewey and Gagné. Part of this chapter includes an initial literature review, partly to identify need. The end of this chapter defines the outline content of the dissertation, chapter by chapter.

1.1. Introduction and motivation behind this work

With over twenty-five years first-hand experience in teaching and learning in Higher Education (HE) this research stems from the desire for continuous improvement in delivery by the author for:

1. Improved methodologies in teaching and learning in Engineering and Technology subjects.
2. The exploitation of modern e-learning tools and blended learning for an enhanced student-centred learning experience.

Part of this experience lies in curriculum development, forming module specifications, defining learning outcomes and course leadership. Within the School of Computing and Engineering, a suite of accredited courses is delivered leading to various titled awards of Bachelor's degrees.

The accreditation for these courses is achieved in recognition for meeting a range of criteria in the delivery of courses in accordance to the UK specification for engineering and technology (This is the UK Standard for Professional Engineering Competence for the education and training of engineers from Technician to Chartered standard) (UK-SPEC, 2013). The accreditation is awarded by a professional governing body (The Institution of Mechanical Engineers and the Institution of Engineering and Technology are two such governing bodies).

The UK Standard for Professional Engineering Competence (UK-SPEC) describes the competence and commitment requirements that have to be met for registration as an Engineering Technician (EngTech), Incorporated Engineer (IEng) or Chartered Engineer (CEng). It gives examples of activities that could demonstrate achievement of the requirements, to enable individuals and employers to find out whether they or their staff can meet the registration requirements. Such competencies are labelled as 'Knowledge and Understanding' and 'Skills'. Qualifications that exemplify the required knowledge and understanding are listed. It does however recognise that there are other ways in which to demonstrate achievement.

The UK-SPEC also provides a glossary of terms some of which will be used within this thesis.

Education enabling technology has progressed in leaps during the last twenty years (Zhang, 2003) along with the needs of the learner. The former is apparent if you consider what is now available through the World Wide Web (WWW), on-line distance learning, interactive and computer aided learning packages, on-line software application learning resources, blogs, YouTube, MOOCs etc. Even social networks such as Facebook and various discussion forums are serving as a means of serving the learner. Education is rapidly evolving, so are the needs and demands of the learner.

Concurrent to this change in learning enabling technology, Technological and Engineering advancements now require the learner to be sufficiently skilled enough for continuous lifelong learning (LLL) and continuous professional development (CPD). Fundamentally however, what has not changed over the years are the ways we define the levels of understanding and mastering any subject. For this, reference is made to the work Benjamin S. Bloom and his Taxonomy of Educational Objectives (Bloom et al., 1956) and Krathwohl (Krathwohl, 2002) as a development of this. This framework was first conceived by Bloom along with a group of educators in 1949 and published in 1956. Bloom's Taxonomy has since undergone a number of revisions and some of the original terminology has changed to what is regarded as more appropriate.

Bloom's Taxonomy of educational objectives is the most highly referenced educational source used for defining KSA (Knowledge, Skills, Attitude or Abilities) within the cognitive domain. The Taxonomy was revised to contain verbs (Anderson, 2002), and has been adapted to be at the core of engineering education (Krathwohl, 2002) to form the UK-SPEC (Standard for Professional Engineering Competence) for monitoring learning outcomes. It is frequently used to structure curriculum learning objectives, assessments and activities. The measurement of these outcomes is, on the whole, a qualitative process and therefore the level of cognitive achievement in a particular subject can be subjective. UK Engineering education focuses on delivering these outcomes.

One of the objectives of this research is to review the changes to Bloom's Taxonomy and adapt it in a novel way in order to apply it to teaching and learning in Engineering and Technology with the aim of achieving a more optimum teaching-learning effectiveness with a deeper level of learning delivered with greater efficiency. It is therefore anticipated that modern e-learning tools, Activity Based Learning (ABL) and Games Based Learning (GBL) will play a key part in this process along with blended learning techniques. A number of renowned educators have written about e-learning and blended learning and their work will be reviewed. Of these, the work of Gilly Salmon (Salmon, 2003), Bryn Holmes and John Gardner (Holmes and Gardner, 2008) are to be included.

Reflective Teaching and Learning has led to broader specific aims than the originally proposed quantifiable novel aspects in teaching and learning in CAD/CAM and closely associated subjects. The reason for this is that it has become evident through reflective Teaching and Learning that no single technique works to best effect with a group of Learners, therefore a blend of techniques need to be considered in accordance to the Learner level and desired Learning Outcomes and the nature of the subject delivered.

One of the key outcomes that is expected to be achieved by this research is whether the researcher can improve the effectiveness of teaching and learning in the delivery of certain engineering and technology modules through varied and blended teaching and e-learning techniques that will encourage students to learn by greater involvement, stimulation and inquisitiveness.

Looking at the range of issues involved it is expected that through this study, it will be possible to utilise a framework for the analysis of effectiveness of current teaching and learning practices in mechanical engineering subject area, develop suitable interventions to improve teaching and learning effectiveness and develop suitable quantitative tools to quantify micro-learning effectiveness.

In order to verify measurable outcomes, a quantitative method will form part of the methodology. Quantitative and qualitative methods will be applied in order to form conclusions on the outcomes.

At the beginning of this research, it was identified that trends in Teaching and Learning in Higher Education were changing fast. This is largely to do with students' expectations for a more enjoyable learning experience. Contributing factors to changes in delivery methods are largely attributed to advances in e-learning, technological changes and the advent of social media and the internet. Information is readily available in almost all field of knowledge and learning 'anytime and anywhere' due to the information superhighway this is more possible than ever. However, guidance is still necessary. The teacher’s role is often one of a facilitator or guide and learning often takes place in a social context and in groups. This was first identified formally by Vygotsky. Even in a formalised learning environment such as the classroom, teaching and learning can take a more relaxed and informal form. It is however, important not to lose sight of the learning outcomes and objectives of delivery. This remains a challenge and therefore a motivation for the research. Or, to put it another way, making learning fun whilst complying with the learning objectives remains just as important as ever. Changes to conventional practices and the motive behind these are partly covered whilst reviewing the work of (Gupta, 2008) and (Euchner, 2014).

One of the early research questions was whether the researcher could improve the effectiveness of teaching and learning whilst delivering engineering and technology subjects through varied and blended teaching and e-learning techniques that will encourage students to learn by greater involvement, stimulation and inquisitiveness. The researcher has gone part way in answering this question as will become apparent in this report.

The researcher also set out to look at a range of issues which would make it possible to utilise a framework for the analysis of effectiveness of current teaching and learning practices in the mechanical engineering subject area and to develop suitable interventions to improve teaching and learning effectiveness and to develop suitable quantitative tools to quantify micro-learning effectiveness. This has also been partly fulfilled to date and continues to be addressed as a research question.

Motivation behind this work is also defined as part of each of the detailed case studies. For example, case study 1 which is based on **Action Research methodology** states that motivation lies in enhancing the education of undergraduates specifically in manufacturing technology in order to enable them to gain a wide appreciation of the technology as pre-requisite knowledge and understanding to deal with practical design problems.

1.2. Background (the narrative of the investigation)

Dating back to 1999 the researcher and a colleague had attempted to integrate two disparate topics on an engineering undergraduate course in an attempt to improve the level and breadth of understanding. Unusually this combined theory and practice in thermodynamics whilst also enabling the students to understand the CAD/CAM process (Computer Aided Design and Computer Aided Manufacture). The process combined theory and practice in an activity with an element of competition. Students had attended lectures on the theory of heat transfer specifically with reference to heat exchangers. The initial delivery was in a very traditional didactic manner and students were given standard equations to assist them in the design of a heat exchanger. Traditionally, this theory would be used to solve theoretical problems on the cooling (or heating) effects of a heat exchanger through tutorial questions and later in the form of written examination questions and numerical problems. Another aspect of the course, which was part of a different module, covered the CAD/CAM process. In isolation, the students were unable to associate these two different subject topics. In the knowledge that engineering often brings together disparate set of principles in order to solve common problems, the researcher had proposed an activity that would elevate learning in both subject topics. This was our first documented experimental attempt at Activity Based Learning (ABL) (Sherwin & Mavromihales,1999). The aim was for students to apply theory in order to design their own heat exchanger. Working in groups, they were given the parameters of input and required output temperatures. They were also given the ambient temperature along with certain other parameters. Working with tubes and manifolds (end plate connectors for the tubing) they were tasked with designing a heat exchanger in accordance to the given design parameters (often referred to as the specification). The heat exchangers would be tested and teams were ranked in accordance to how close they met the required output temperature. They were also required to design the end plate connectors, these were designed using CAD and engineering technical drawings were issued to a workshop. As they had to be manufactured within the department's workshop on a CNC (Computer Numerical Control) machine, students were educated in the CAD/CAM process. It was therefore made clear to them that the true dimensions of the graphics representing the plates and the holes for the tubes would result in the actual machined size (due to the integrated CAD/CAM process). The physical drawings merely served as a means of checking the specified dimensions for verification once the plates were complete. Although this assignment was primarily associated with the subject of thermodynamics, it introduced other elements of the curriculum which were associated with other modules. These were:

- Engineering Graphical Communication (including CAD), and
- The CAD/CAM process.

This was our early attempt at Activity Based Learning applied in what the researcher now refers to as Integrated Concurrent Engineering Education (ICEE). ICEE attempts to raise students' awareness of how parts of the curriculum covered in different subjects or modules are applied in a wider context, thus closely replicating actual professional life experiences and expectations. It is intended to take learning to a higher level for higher order thinking. In Sherwin & Mavromihales,1999, although we had not recorded any data that depicted the students' learning experience (only data that quantified the results of the activity in the form of performance data and rankings), as educators we instinctively knew that the students had enjoyed the learning experience. They were enthusiastic, engrossed, and competitive and were motivated to understand the theory in order to apply it to the activity. We could therefore see evidence of stimulation of the affective domain in learning.

The work that was to follow was based on the development of an e-learning package (Unver and Mavromihales, 2001). Driven by a government initiative to establish what was known at the time as The University for Life (UOL), which was an umbrella organisation for the creation of new markets for education, the organisation sought to take advantage of new learning methods, of which e-Learning was included. Following a project proposal, we sought to develop on-line and CD-based digital interactive teaching material – Multimedia Learning for Industry. Although 3D CAD and CAM software was widely available for industry at that time, it primarily produced part programs (coding) for machining. There was a distinct lack of e-Learning material in this field for college and university education. What was available was limited so we developed an e-Learning package utilising 3D interactive CAL (Computer Aided Learning) program for training in CNC (Computer Numerical Control).

During the early part of the noughties (2000 onwards) the use of Rapid Prototyping techniques was gaining widespread popularity within educational institutions. At the time the author had instigated the purchase of a ZCorp 3D printer in order to incorporate it within the curriculum of engineering education, specifically in CAD/CAM (Mavromihales and Weston, 2002). Our students were actively involved in the Formula Student project at that time (https://en.wikipedia.org/wiki/Formula_Student), which is a student engineering competition held annually in the UK. The competition is administered and organised by the Institution of Mechanical Engineers, the professional governing body of Mechanical Engineering. Student teams from around the world design, build, test, and race a small-scale formula style racing car. The cars are judged on a number of criteria. This posed an opportunity for more Activity Based Learning within the curriculum during which students would apply knowledge gained from didactic sessions in a creative manner. This would also promote the following:

- Reinforcing existing knowledge
- Develop skills (in both design creativity and a rapidly emerging Additive Manufacturing Techniques)
- Promote higher order understanding through synthesis to problem solving.

This activity would also pose an opportunity for Integrated Concurrent Engineering Education where students are applying wider knowledge and skills gained in disparate subjects to generate a creative solution to a design problem.

1.3. Motivation for research work

From the outset of this research, it was identified that that trends in Teaching and Learning in Higher Education were changing fast. Engineering and Technology subjects have not been exempt of these trends and since the earlier days of this research, several cases of radical ‘new’ and novel engineering courses have come to light in the media. Although sometimes controversial and considered by many as a paradigm shift, questions arose as to whether the radical and ‘disruptive’ changes go too far. Are the days of the traditional autocratic didactic lecture numbered?

An example has been a new university specialising in engineering courses that intends to abandon lectures and teach students in small project teams. Assessments by examination are to be limited to no more than 20% of the overall course assessment with the remainder gained through projects and activities to encourage risk and failure in order to learn. The new university based in Hereford was provisionally to name the course, ‘New Model in Technology and Engineering’ (NMiTE). It featured in the Times on 5th September 2016 (Hurst, G 2016 and https://www.thetimes.co.uk/article/new-university-to-abandon-lectures-and-charge-12-000-383ltgt95).

Inevitably, such a course would be costly to fund due to greater demands in resources and reduced staff/student ratios. Would it however, provide a ‘superior’ engineering education that better equips graduates with the skills and knowledge that industry expects?

Another example is that of Olin College, Needham, Massachusetts, USA, which has an engineering curriculum which is built around hands-on engineering and design projects (Euchner, 2014).

Changing trends in Teaching and Learning in Higher Education can also largely be attributed to the changing expectations of students for a more enjoyable learning experience. Contributing factors to changes in delivery methods are largely attributed to advances in e-learning, technological changes and the advent of social media and the internet. Information is readily available in almost all fields of knowledge and learning ‘anytime and anywhere’ due to the information superhighway. Quoting Prensky, (2001, p.1):

> “Our students have changed radically. Today’s students are no longer the people our educational system was designed to teach”.

However, guidance is still necessary. The teacher’s role is often one of a facilitator or guide and learning often takes place in a social context and in groups. This was first identified by Vygotsky (Vygotsky & Cole, 1977 and Vygotsky, 1978). Even in a formalised learning environment such as the classroom, teaching and learning can take a more relaxed and informal form. It is however, important not to lose sight of the learning outcomes and objectives of delivery. This remains a challenge and therefore a motivation for the research. Alternatively, to put it another way, making learning fun whilst complying with the learning objectives remains just as important as ever. As this work has progressed, its specific aims have broadened and led to the inclusion of quantifiable novel aspects in teaching and learning within the subject area of CAD/CAM and closely associated subjects. There is also the anticipation that the methodology can prove to be just as effective in other engineering and technology subjects. The researcher has also come to recognise that no single techniques consistently work to best effect with a group of learners, therefore a blend of techniques need to be considered in accordance to the learner level and desired learning outcomes and nature of the subject delivered.

One of the early research questions was whether we could improve the effectiveness of teaching and learning whilst delivering engineering and technology subjects through varied and blended teaching and e-learning techniques that will encourage students to learn by greater involvement, stimulation and inquisitiveness. The researcher has gone part way in answering this question as will become apparent in this report through the case examples. The researcher also set out to look at a range of issues, which would make it possible to utilise a framework to evaluate effectiveness of current teaching and learning practices in the mechanical engineering subject area and to develop suitable interventions to improve teaching and learning effectiveness and to develop suitable quantitative tools for micro-learning effectiveness. This has largely been fulfilled to date and continues to be subject to further research beyond this report.

1.4. Current and future state of engineering education and career prospects

In the European Union (EU), including the UK, there are a number of countries reporting of shortages in different engineering fields. This also holds true in the USA, as becomes apparent in the literature review. These shortages are reported as ‘bottlenecks’. By this term, it is understood that employers expect future problems in satisfying vacancies as they have done in the past. Mechanical Engineers rank amongst the highest (top ten) of engineering profession shortfall. In 2017 alone, the annual shortfall, at a conservative estimate, stood at 20,000. The Institution of Engineering and Technology (IET, 2019 revealed in a report that 62 per cent of engineering employers say that graduates cannot offer the right skills. The report is available at (https://www.theiet.org/impact-society/factfiles/education-factfiles/iet-skills-survey/iet-skills-survey-2019/). This indicates that engineering education is currently failing a considerable number of graduates in the discipline. However, it is also suggested that there are deficiencies in schools and universities in adequately preparing future engineers for their debut in the workforce. STEM (science, technology, engineering and maths) subjects have been unpopular. Schools are generally unable to encourage significant number of pupils to take these subjects at A-level. Plugging the skills gap will be a long process (https://www.randstad.co.uk/job-seeker/career-hub/archives/uk-engineering-facing-a-skills-crisis_1101/).

Engineering is recognised as a critical part of the UK economy, both by direct contributions to turnover and employment and 'multiplier' effect. 27% of registered enterprises in the UK are in the engineering sector (2018) and the number is rising annually yet the supply of a skilled workforce is not growing accordingly. This contributes 23% of the UK's turnover.

(https://www.engineeringuk.com/media/1576/7444_enguk18_synopsis_standalone_aw.pdf).

The Higher Education sector has seen significant changes during the last few years and 2017 saw the emergence of HERA (Higher Education and Research Act), with its aim to create competition and choice, boost productivity in the economy, ensure value for students and strengthen the UK's research and Innovation sector. A new regulator was appointed the Office for Students (OfS), who oversee the Teaching Excellence Framework (TEF), which is an assessment of teaching quality. 'Employability' of graduates is one of the factors applied for grading. The hope is that TEF will contribute to addressing skills shortages in STEM areas where there have been concerns around the suitability of graduates being 'work ready'. The metrics used by TEF to measure employability have raised concerns. TEF grades institutions with either Gold, Silver or Bronze standard. The university in which the research has been conducted is a post 1992 university which has been awarded a Gold TEF standard, which is the highest of the three standards. The future plan is for the Office for Students to award at subject level as opposed to institutional level. This would imply that the Department of Engineering and Technology within the School of Computing and Engineering will be under greater scrutiny. Teaching excellence and progressing methods of delivery in teaching and learning are therefore vitally as important as they ever have been. This applies to the sector as a whole.

The largest flow of newly skilled talent into the engineering workforce comes directly from education (including Further and Higher Education). This is despite the growing number apprenticeships that have been introduced in recent years, which, in accordance to data in 2017 are now showing signs of decline in take-up. This has coincided with the introduction of the apprenticeship levy.

A report was compiled and published in January 2017 by the Royal Academy of Engineering in response to the House of Commons Science and Technology Committee inquiry into closing the STEM skills gap.

(https://www.raeng.org.uk/publications/responses/closing-the-stem-skills-gap)

The report listed some key messages on the basis of its findings. The Academy undertakes activities in schools, colleges and universities to encourage young people to become engineers. It aims to change perceptions of engineering, leading on diversity, equality and inclusion for the sector, improving the quality of teaching and learning across STEM subjects, providing professional development for engineers and influencing government policy to increase participation and attainment in STEM. It therefore focusses on key problematic issues that are hindering the engineering profession. It is such issues that the researcher is concerned in addressing.

Engineering education, especially the Higher Education sector, is facing certain concerns. One of the major concerns is that between each educational stage, there is potential for ‘leakage’ from the pipeline, as individuals make voluntary decisions about their progression. Although a certain amount of drop-out is inevitable, as it is in any subject area or formally delivered course, often due to uncertainty as to the right career path to take especially for many young people. The image portrayed of an engineering career along with the methods of delivering education of engineering and technology subjects can go a long way to reduce ‘leakage’. This has already been recognised by several works which indicate that suitably designed interventions can be used to develop novel teaching and learning processes for better teaching effectiveness. Euchner, J (2014), puts across, in a very effective way, the views of Rick Miller that seeks to redefine undergraduate engineering education and attract more students in the profession. Rick Miller (http://www.olin.edu/faculty/profile/richard-miller/) is the founder and first President of Olin College, USA and is renowned for his radical methods and thoughts on delivering engineering education. He describes engineering education as ‘a very leaky pipeline’ because it loses so many undergraduates every year. This along with the lack of attracting females in the profession indicates that there are underlying causes for concern. Miller claims that at the core of the problem is that engineering students are often not very engaged in their education. Traditionally most courses do analysis and calculus with the unspoken assumption that more maths is always better and that the more advanced maths that is applied makes for a better engineer. Miller challenges this with some very valid arguments and draws on some interesting analogies and observations. If the researcher aims to develop and prepare people to be innovators, to be creative and develop new ideas then this is the worst way in which the researcher can deliver an engineering education whilst drawing in and engaging students. Engineering presents itself too much for being Technical rather than Creative. Miller defines the term engineer as

> “a person who envisions what has never been, and does whatever it takes to make it happen. The science is just a set of power tools that enable engineers to make it happen; they are not fundamentally what an engineer is or does”

Another interesting point that Miller makes is in the analogy to music as he believes that there may be insights (for engineering) in the education of musicians. If you sent a child prodigy with a talent in the violin to a top academy of music and music education was like engineering education, what could they expect? Miller puts it like this:

> ‘In the first year, they would study the theory of sound: the theory of vibrations of strings, mode shapes and natural frequencies, and how instruments work from a physics point of view. The second year, they would take courses in music theory: they would come to understand point and counterpoint, harmony, and all the things that make music work in the abstract. In the third year, they might begin to study orchestration. Then, if they were still there in the fourth year, we might ask them to play some scales on a real violin. And that’s it; then they would graduate’.

There would not be that many musicians.

Miller has some very valid points in his criticism on engineering education as generally engineering education requires thinking that goes beyond technical problem solving, to the process of deep, dynamic collaboration. A means by which to address Miller's concerns is through the introduction of Games Based Learning, with a practical problem solving approach. This will offer a more pragmatic approach to learning whilst also offering the opportunity for quantifying its effectiveness through learner participation, results and progression rates.

Reise et al., (2014) acknowledge that cognitive science has proven that active forms of participation offer more effective forms of teaching and learning than methods that only rely on reflective learning (http://www.qotfc.edu.au/resource/?page=65375). The authors identified four games that relate to aspects of sustainability, which also have innovative game approaches. They claim these games comply with the requirements that instruction is best organised in a way that it integrates four learning dimensions (McFarland et al., 2013). These are:

1. Active experimentation
2. Reflective observation
3. Concrete experience
4. Abstract conceptualization.

The authors also assert that GBL provide teaching methods, which have the potential to integrate all four learning dimensions into their instruction especially active experimentation in which traditional forms of teaching like lectures and seminars often lack. This can result in greater motivation, action and retention of students whilst also providing a more efficient means of knowledge transfer and skills according to Potente et al., (2013). GBL therefore build a powerful approach to enhanced learning productivity in the learning environment. Based on the four learning dimensions the authors developed a learning game, which is aimed to educate engineers on the business game for total life cycle management where teams of students represent competing companies from the automotive industry. The game aims to develop new business strategies and personnel are required to implement strategies. The end product is an electric scooter and a value is given to each team based on the sustainability and sales of the product as determined by a formulated mathematical score. The outcome of the score is based on qualitative criteria set by the assessors. The learning process and its outcomes do not appear to have been quantified by Potente et al., (2013).

The game described in this article is a manual simulation game with little or computer interaction. The consequence of this has been the need for tutor intervention to act as a referee. However, the author proposes future work in the form of a web based game with the creation of a user interface enabling participants to access real-time information on the state of play. Such a development would invite student participation and is based on a study in which students learn further whilst engaged in game development (Garneli et al., 2013).

In Sherwin & Mavromihales, (1999), the four learning dimensions identified by McFarland et al., (2013) were inadvertently applied, so although the application was instinctive, it resulted in the success of the activity. Learners were <u>***actively experimenting***</u> through trials of their own heat exchanger design. The performance of their individual design as compared to that of their peers was validated through <u>***observation and reflection***</u> (with questions such as why have my peers performed better or worse). The process of applying heat transfer theory into what was perceived to be a practical working design (the design process) offered the opportunity for <u>***abstract conceptualization***</u>. The complete learning process of theory and application of Integrated Concurrent Engineering Education, learning by doing had resulted in a positive <u>***concrete experience***</u>.

In a special report published by the editor of the Journal of Engineering Education (Radcliffe, 2006), the decline in engineering interest by the American youth was reported causing a corresponding shrinkage in the supply of technological innovation. The same applies to the UK based engineering sector and as a predicted consequence of this is the threat for the decline in national prosperity. The report called for supported research for the transfer on revised methods, instruments and metrics in engineering education in order to improve the engineering learning environment and make it more conducive to learning. It recommended changes to learning processes, different kinds of domain knowledge, socio-cultural factors, and teaching pedagogies. Such changes are also compelled by engineering enterprises under a new rationale for us to consider how future generations of engineers are educated. The authors of the report called for a transformational change rather than an incremental change for long lasting changes to the educational system (as supported by other researchers such as Streveler and Smith, 2006). This can only be driven through research in engineering education which will drive the changes to improve technical fluency of students and teachers, reports the author. Such research will provide principles, methodologies and educational practices in order to

> *"continually build innovative curricula that lead contemporary engineering practice and meet the needs of the nation and the world".*

It is only through such changes that national and global challenges can be effectively addressed. Reference is made to a report (Radcliffe, 2006), published by the Journal of Engineering Education in which five research areas are presented which can collectively serve as a foundation for the Engineering Education discipline. This is anticipated to increase understanding in the following areas:

- What knowledge and understanding are engineers of the future required to possess?
- How content is delivered, learnt and how will it be assessed?
- How to design future learning environments?

By addressing these questions through engineering educational research it is believed that the researcher shall facilitate ability to attract, engage and retain diverse talent that is needed for a more prosperous and inclusive world of engineers.

There are five areas of research identified by the author of the report for the new Engineering Education which can be investigated either independently or integrated. These areas are:

- Engineering Epistemologies
- Engineering Learning Mechanisms
- Engineering Learning Systems
- Engineering Diversity and Inclusiveness
- Engineering Assessment.

Area 1 – Engineering Epistemologies refers to research on what constitutes engineering thinking and knowledge within contexts now and in the future. Although we know about the essence of thinking and knowing, there is a shortfall of research which will help facilitate improvements in the characterisation of engineering education from a social ethical as well as technical aspect, within dynamic and multidisciplinary environments.

Area 2 – Engineering Learning Mechanisms refers to research on engineering learners' developing knowledge and competencies in context. Expertise is lost through retirement and therefore research that defines what knowledge, skills and attitudes learners bring to engineering education which influences what they learn and their developed ability to learn, think problem solve like an engineer. This challenges current assumptions on how we teach and assess for understanding.

Area 3 – Engineering Learning Systems refers to research on the instructional culture, institutional infrastructure and epistemology of engineering educators. The need for this area of research is attributed to the rapid pace of innovation and the need for engineers to repeatedly learn about and exploit the capabilities of new discoveries. This implies the creation of new formal and informal types of learning environments and experiences within a range of settings (classrooms. Labs, studios, showcasing, synchronous and asynchronous e-learning).

Area 4 – Engineering Diversity and Inclusiveness refers to research on how diverse human talents contribute solutions to the social and global challenges and relevance of our profession. It is reported that engineering and society are inter-related in that each shapes the other. Attracting individuals within engineering who are capable of thinking and working across diverse perspectives is important in that it creates a future workforce with diverse talents to encourage innovation, creativity and global understanding for a more equal, inclusive and prosperous world. By developing the ability to work in multi-disciplinary teams, individuals learn from the other disciplines. The experience is then transferred into engineering.

Area 5 – Engineering Assessment refers to research on, and the development of, assessment methods, instruments and metrics to inform engineering education practice and learning. Through information gained by valid and reliable assessment feedback we are able to assess the general 'state' of educational in terms of student engagement and learning and teaching methods and systems. It is claimed that, the development of and adoption of new educational methodologies, innovative methods of delivery and instruments specific to engineering domain knowledge, will be influenced by research methodological approaches (be it traditional or emerging) as well as faculty/departmental epistemological views. It is also claimed that through investigative methods in assessment research, it may be possible to initiate such elements as psychometrics that are associated with designing appropriate assessments that are unique to engineering.

1.5. Other cited work on engineering education – future requirements and competencies

Streveler and Smith, (2006), set out to trace the landscape of engineering education research within an editorial review. They report on the exciting opportunities that exist to build knowledge that will make a difference in engineering education curriculum and pedagogy. A strong community need is identified and supported through citations (Fortenberry, 2006, Gabriele, 2005). The question is posed as to where the emerging knowledge on engineering education research should be directed and make suggestions; They suggest movement beyond the classroom and a need for broader knowledge of literature encompassing psychological, sociological and anthropological (as well as educational) in order to form conceptual frameworks. So although there is a common perception that all engineering education research must be confined to the classroom, it is suggested that, valuable studies can be conducted in other contexts.

Johri and Olds, (2014), report that until the early 2000s engineering education research (EER) lacked definition as a discipline. It was not until the landmark issue of the Journal of Engineering Education in 2005 when senior scholars in this field argued for a stronger research agenda to be driven by theoretical and empirical research (Haghighi, 2005). In an editorial review, Johri and Olds, (2014), report that despite the growth of the field since the early 2000s, there was still no comprehensive handbook on the field of EER until the publication of the Cambridge Handbook of Engineering Education Research (known as CHEER) in 2014. The only previous publication in the form of a book prior to this was John Heywood's Engineering Education: Research and Development in Curriculum and instruction-related issues (2005). Where CHEER differs is in that it focussed on theoretical and empirical developments in engineering education thus signalling the maturity of the

EER community. In the comprehensive review of CHEER, Johri and Olds, (2014) identify missing topics which include motivation, team work and collaboration, laboratory instruction, graduate education, continuing professional education and many others. Approaches such as action research are also missing from the handbook. The coverage is therefore claimed to be incomplete and the reason identified by the reviewers is that there is, as yet, insufficient research on them within engineering education, despite their importance and interest within the field as a whole. Missing work within the handbook was also attributed to lack of methodological development within the field. There are several questions that the editors had raised during the editorial process which identify gaps. Some of these questions can be summarised as follows:

- Do the insights gained from EER apply to other populations? (i.e. cultural differences)
- Is there enough knowledge generated that can be applied by practitioners in engineering education rather than engineering education researchers?
- What would theoretical and methodological innovations in engineering education look like?
- What is the value to the community and how can this be judged?

Another issue identified and brought to notice within the review is the multitude of references from conference proceedings (particularly ASEE/IEEE frontiers in Education Conferences). The key point made is that there is lack of conversion of conference papers into journal articles, which are a more prestigious form of an archival publication, state Johri and Olds, (2014). This can also bring to question the prestigious reputation that certain conferences hold and suggests greater selectiveness.

The Accreditation Board for Engineering and Technology (ABET) is the equivalent benchmark validation standard in the USA to the UK-SPEC. (Passow, 2012), carried out an extensive review of the competencies of engineering graduates with reference to the competencies stated. It identified the five most important competences common to a range of engineering disciplines as being team-working, data analysis, problem solving and communication. The three competencies which were regarded as being of lesser importance were contemporary issues ('knowledge of contemporary issues that affect my work'), carrying out experimental work and impact ('understanding the social, economic and environmental impact of my work').All competencies were as listed in ABET and their importance was established through questioning experienced graduates as to which of the competencies had proven to be of most value whilst in practice. The key question of the author of this study was:

> *"Which ABET competencies do engineering graduates rate as most and least important for professional practice?"*

The following definition of competencies was used:

> *"the knowledge, skills, abilities, attitudes, and other characteristics that enable a person to perform skilfully (i.e., to make sound decisions and take effective action) in complex and uncertain situations such as professional work, civic engagement, and personal life".*

The target group consisted of more than 4,000 graduates from a single (unspecified) University, within ten years of graduating and the target population was engineering graduates in the USA. The survey was conducted post 2000 (during seven consecutive years). The graduates were asked to rate the most and least important competencies for professional practice. The subject areas were almost entirely from engineering disciplines but also included computer science and computer engineering. There were eleven disciplines in total therefore there were some variances in the scores for the competencies depending on the precise subject area. There were certain side issues that were also considered such as differences in responses between demographic groups, stability of results over time (as the survey was conducted over several years), consistency across engineering fields of practice settings (i.e. technical sales vs design) and statistical significance. It is claimed that such surveys help in faculty outcomes-based quality assurance as they pose the question of adequacy of graduates' performance on competencies form the ABET (or UK-SPEC) list.

The survey used a graduation scale from 1 to 5 for respondents to score the importance of each competency. The lowest score from the presented list was 3.3 and the highest was 5. The top four competencies were significantly higher than the lower three. There were other competencies, which fell in the mid-range but the cluster range of response scores varied depending on work environment or academic discipline (i.e. Computer science or mechanical engineering) and not demographics. The top clusters of competencies (regardless of discipline) were:

- *Teamwork*
- *Communication*
- *Data analysis*
- *Problem solving.*

The three competencies at the bottom were

- *Contemporary issues*
- *Design of experiments*
- *Understanding the impact of one's work.*

Note: The bottom three competencies are not included in ABET document and the only respondents that scored these high were graduates working outside of traditional engineering work. The strength of this research was in highlighting the four most sought after attributes from graduate engineers. Its weakness was that it took a general approach which overlooked competencies specifically desired by minority (or specialist) engineering sectors, or specific roles of engineers within mechanical engineering. An example would be an engineer assigned with the responsibility of defining a health and safety policy. Another example is being able to identify the impact of ethical issues whilst assigned with responsibility for procurement.

Figure 1.1 graphically indicates the average scores (across all 11 disciplines) for each of the competencies. The dots therefore represent the overall average from 2115 engineering graduates.

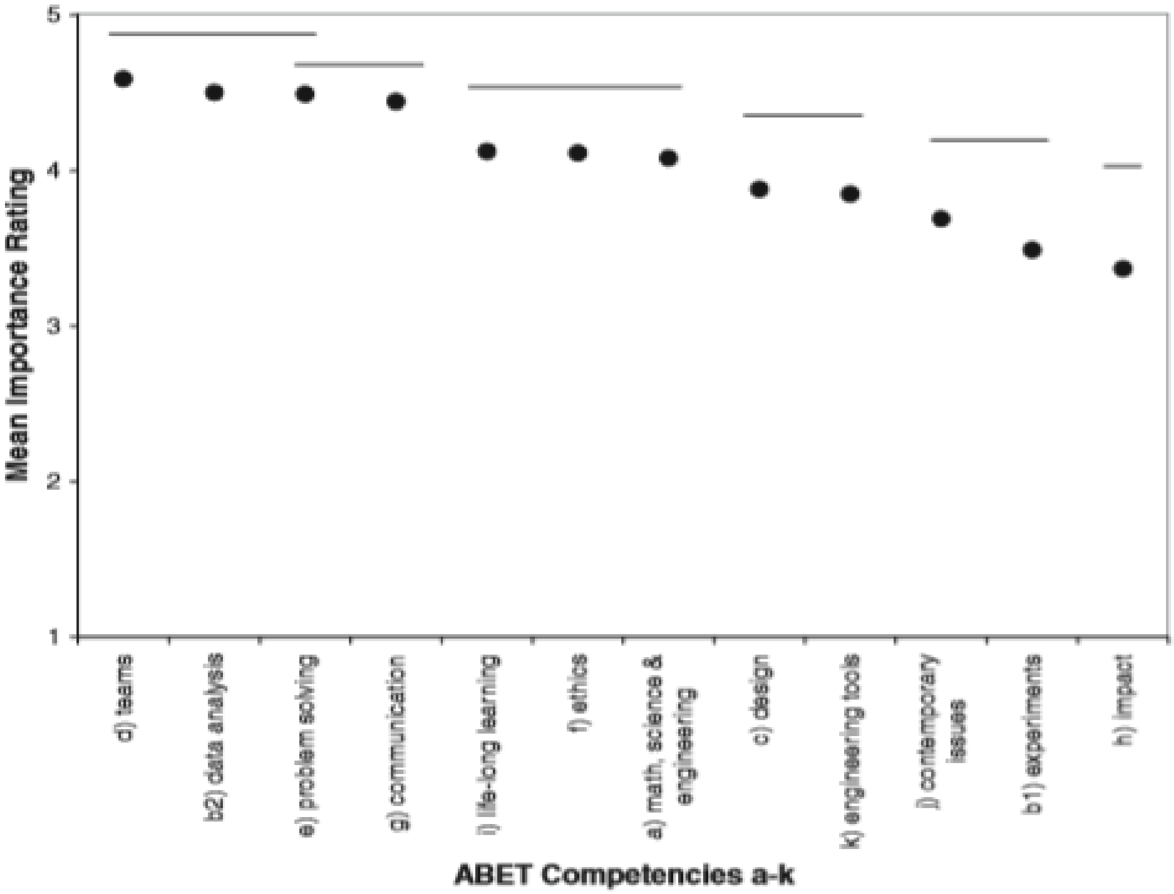


Figure 1.1: Importance ratings for the ABET competencies. The survey question was: “Please rate how important the following competencies and attitudes have been to you in your professional experience.”

The ratings descriptors were:

5 = ‘extremely important’

4 = ‘quite important’

3 = ‘somewhat important’

2 = ‘slightly important’

1 = ‘not at all important’.

All ratings in the study have mean ratings greater than ‘somewhat important’. Reproduced from (Passow, 2012).

1.6. Research aims and objectives

The aim of this PhD is to critically evaluate the use of GBL within an undergraduate programme in Mechanical Design at a post 1992 university and determine its contribution to students' learning. To do this, the researcher has sought to establish students' perception of GBL as a way of learning within their degree and determine whether there is a quantifiable causal relationship between its use and students' learning. This has involved building on the researcher's published research into GBL and Active Learning within an undergraduate programme in Mechanical Engineering at a post 1992 university.

As such, this PhD's objectives are:

1. To critically evaluate Mechanical Engineering students' perceptions of GBL learning within an undergraduate programme at a post 1992 university.
2. To determine to what extent there is a quantifiable causal relationship between the use of GBL within an undergraduate programme in Mechanical Engineering at a post 1992 university and improved student learning.
3. To establish to what extent the findings and what has been learned from the use of GBL within a Mechanical Design undergraduate degree can be applied more generally within university-based Engineering Education?
4. To develop an optimum blend of e-learning interventions with traditional teaching systems to obtain maximum teaching-learning effectiveness.

The researcher aims to build on Bloom's Taxonomy in order to deepen understanding, by quantifiable means, of teaching and learning in engineering and technology. E-learning techniques and gamification theory are to be blended in the process. The researcher aims to build on Bloom's Taxonomy in order to deepen understanding, by quantifiable means, of teaching and learning in engineering and technology. E-learning techniques and gamification theory are to be blended in the process.

More generally the researcher aims to:

Enhance the Teaching and Learning process by bridging the gap between learner expectations and the educator in the general subject area of Engineering and quantify the Teaching and Learning effectiveness. The objectives for this are:

1. To enhance the level of Teaching and Learning provision
2. To develop suitable interventions to improve teaching effectiveness
3. To quantify the teaching and learning effectiveness.

With reference to the first research objective (to enhance the level of Teaching and Learning provision) the following three sub-objectives are identified:

1i. To identify details of existing frameworks in teaching and learning

1ii.To identify the application of theoretical framework to ascertain Teaching and Learning effectiveness

1iii.To develop an improved theoretical framework to Teaching and Learning in CAD/CAM and Engineering Design.

With reference to the second research objective (To develop suitable interventions to improve teaching effectiveness) the following three sub-objectives are identified:

2i. Applications of Games Based Learning in the Teaching and Learning process

2ii. Application of flipped learning approaches in the Teaching and Learning process

2iii. Application of integrated Games Based Learning, flipped learning techniques and Activity Based Learning.

With reference to the third research objective (To quantify the teaching and learning effectiveness) the two sub-objectives identified below will utilise quantitative techniques (a novel aspect of this work):

3i. Evaluation of Games Based Learning and Flipped Learning interventions in Teaching and Learning effectiveness

3ii.The development of qualitative model to reflect incremental learning enhancement in CAD/CAM and associated areas such as Manufacturing Technology and Design.

By achieving the outlined aims and objectives, this PhD contributes to what is already known about how Mechanical Engineering undergraduates learn within their degree and adds “another brick” (Wellington, 2000, p.137) to the knowledge wall of Engineering education. To do this, the researcher has employed an action research methodology to firstly better understand his practice and secondly change it (Kemmis, McTaggart, and Nixon, 2014).

1.7. Outline of chapters in this thesis

The work presented in this thesis is organised in ten chapters, the first two of which present the necessary background material. The remaining chapters present the original material in the form of specific case studies. Outcomes from the case studies are presented in the latter chapters where analysis, discussion, conclusions and future work are presented. The novel content of the research is stated within the latter chapters.

Chapter 1 presents an overview of the research and the background associated with it. It describes the historical background to the work along with the narrative that has led to the motivation for it. Part of the introductory chapter includes identification of need for ongoing research in the field of engineering education research. In order to put the research in context, part of chapter one considers the work of well-known educational philosophers and educational psychologists including Len Vygotsky, Benjamin Bloom, David Krathwohl, Lorin Anderson, Malcolm Knowles, John Dewey and Robert Gagné.

Although chapter one is not intended to be a main literature review it cites the work of profound researchers in educational research who have based their work on the established educational frameworks of the pioneers that preceded them. This was deemed necessary as part of the background introduction to the research.

Chapter 2 is an extensive literature review. Due to several facets associated with engineering education research the researcher has organised the literature under the following themes: in e-learning, blended learning, flipped learning, teaching and learning strategies, games based learning, active learning, project based learning, activity based learning, problem based learning, collaborative learning, action research methodology and engineering education research. The common theme is engineering educational research. This chapter is key in the identification of gaps in the existing knowledge and the study's research questions and identifying novel aspects of this work.

Although chapter 2 forms the core of the literature review, further reviews and citations are included in later chapters as part of the case studies. Most of the case studies are based on own published work (as indicated at the start of each case study chapter). To have removed cited work from the case studies would have resulted in removing it from the context in which it was originally intended for publication purposes. The researcher has however removed results, conclusions, recommendations and future work from the case studies in order to include them in separate chapters for improved organisation.

Chapter 3 outlines the procedure of the research case studies and outlines the research methodology, research frameworks, identifies gaps in knowledge within the research field and poses several key research questions that draw on the work of the case studies. Research questions are addressed within the individual case studies which are specific to the case example as well as the more general research questions. All research questions are presented within this chapter in order to put them in the overall context of the research.

Chapter 4 presents the first case study which has been based on delivery of a module on manufacturing technology and workshop practice. The flipped classroom teaching and learning strategy has been used along with implementation of an electronic voting system. Both qualitative and quantitative results have been obtained and these are analysed and discussed. Chapter 4 is self-referenced as it is based on an earlier publication. It extends previously published work in order to explore research questions.

Chapter 5 presents the second case study and considers the application of Games Based Learning (GBL) as part of active learning in 3D Computer Aided Design (CAD) Assembly in mechanical engineering education. This case study also evaluates the results, qualitatively and quantitative. Chapter 5 is self-referenced as it is based on an earlier publication. The second case study in this chapter is an extension to the original case study described in the same chapter (GBL) but with the gamification aspect removed. Its novel aspects lie in revisiting and reinforcing previously gained knowledge from technical graphics, CAD representation (for both 2D drawing and 3D assembly) and considers design aspects such as tolerances (limits and fits) and surface finish. The case is one in which a physical artefact is used by collaborative learners, working in pairs.

Chapter 6 presents the third case study and considers a novel application that combines GBL and Activity Based Learning (ABL) as part of studio based activity in mechanical engineering design. It draws on and reinforces previously gained knowledge from at least two modules in order to constructively reinforce knowledge. Aspects of collaborative learning are also demonstrated and discussed as part of this case study. Although the analysis of the results of this case study is qualitatively, it also presents some quantitative results.

Chapter 7 contains the analysis from the case studies and a summary form of each.

Chapter 8 initially revisits the original aims, objectives and research questions before it draws conclusions based on the analysis of the case study results. It discusses these results in order to find the common thread between action learning activities and summarises the findings linked to the original research questions, identifying the novelty of the work, closed gaps and the study's contribution to the knowledge base of Engineering education.

Chapter 9 makes recommendations for future work as a continuation to the work presented in this thesis.

1.8. Summary

Chapter 1 forms an important foreword that leads us into the proceeding chapters in that it considers the motivation behind the research through a narrative. It addresses key shortcomings in teaching and learning with particular reference to engineering and technology and hence identifies the need for ongoing education research. Although it reviews some previous research in engineering education and introduces the work of educational philosophers and educational psychologists it does not form the main body of the literature review that follows within chapter 2. The work reviewed as part of this chapter is the ‘foundation stone’ to what is to follow and it helps us identify some early gaps in knowledge as well as potential novel aspects of the work. The end of the chapter defines the outline content of the dissertation, chapter by chapter.

Chapter 2 – Literature Review

This chapter contains the main body of the literature review. There are several facets associated with engineering education research and as such the researcher has categorised the review of previous work in to a number of related areas that contain attributes associated with the work. The common theme is in engineering educational research. The chapter is key in identifying gaps in knowledge and thus informing the design of the study and the research questions outlined later in chapter 3.

2.1. Introduction

In chapter 1 the researcher considered some well-established pedagogical frameworks associated with historically renowned educational theorists, philosophers and educational psychologists. The work of Bloom, Vygotsky, Knowles, Dewey and Gagné were milestones in instructional theory and practice and has been scrutinised by many educational theorists and researchers over decades. More recently, their instructional theories have been adopted and adapted in accordance to technology driven changes in educational curricula. In this chapter the researcher shall review further work from renowned theorists as well as the work of several researchers who have applied such frameworks in areas such as e-Learning, Blended Learning, Flipped Classroom Learning, Activity-Based Learning, Games Based Learning, and Project Based Learning. More specifically, the researcher shall consider teaching and learning methodologies as well as social aspects of teaching and learning. The review of previous work will lead us to:

1. Identify knowledge gaps
2. Present the research questions
3. Define the scope of the research and
4. Specify novel aspects.

Key search words used as part of the literature search and individual case studies:

Engineering Education, Engineering Education Research, Action Research, Teaching and Learning strategy, Flipped Classroom, Flipped Learning, Engineering Curriculum Design, Undergraduate Engineering Courses, e-Learning, Electronic Voting Systems (EVS), Blended Learning, Game-based learning (GBL), Game design, Motivated learning, Group collaboration in learning, Collaborative learning, Cooperative learning, Active Learning, Project Based Learning, Problem Based Learning, Activity Based Learning, Team Based Learning.

Note: The search terms were refined as the literature review progressed so although there are a huge number of references with pedagogical content knowledge the research specifically looked for engineering pedagogy in order to contextualize the work. The same applied in the literature search for Games Based Learning of which most work is associated with digital computer based serious games. Some literature items associated with search terms were regarded as being normally out of scope; for example, e-learning and engineering specific pedagogies were either sparse in existence or, in the search for e-learning literature, focused entirely on on-line asynchronous learning. Such items were reviewed before being excluded and where appropriate were retained. Synonyms were used where appropriate to ensure that important items are not inadvertently missed; for example, Active Learning, Project Based Learning, Problem Based Learning, Activity Based Learning, Team Based Learning. The inclusion criteria for selecting literature were:

1. Studies could use any methods (qualitative, quantitative or mixed)
2. Studies could have taken place in any country, but the findings had to be accessible in English
3. The date of publications from 2000 or later were preferred but older studies that offered important insights or that were the basis of significant milestone future work was included.

The full bibliography contains more than 250 items. A smaller subset of the most relevant articles was selected for detailed examination.

2.2 Related work on educational frameworks

2.2.1 Levels of understanding and learning styles

The previous section gave mention to some of the themes along which this research is proposed to be developed. The narrative and motivation behind this work was given and in order to develop research questions a thorough literature search and review has been undertaken to identify knowledge gaps in selected areas of research. The review of previous work will be categorised into selected relevant areas such as e-Learning, Blended Learning, Educational Frameworks, Activity Based Learning, Games Based Learning, Project Based Learning and Collaborative Learning. The main body of the review is contained in chapter 2.

The first area of research that is proposed to be thoroughly developed is that of frameworks for analysing teaching and learning effectiveness. As part of the process of considering cause and effect of approaches to teaching and learning the researcher has explored theoretical frameworks, associated with education. Such theoretical frameworks can be used to explain, predict and understand phenomena, as well as challenge and extend existing knowledge, within the limits of critical bounding assumptions. Important in this research, is a structure that can hold or support the theory of the research. It is hoped that the research study will be strengthened by continued consideration of such frameworks, thus developing one or more to underpin the work.

2.2.2 Vygotsky and the social aspects of learning-Social Constructivism

One of the frameworks to be considered is:

Vygotsky's framework which advocates discussion-based learning using Socratic Questioning Methods. Lev Vygotsky was a Russian teacher and psychologist whose learning theories were first developed in Russia within a community in which social, cultural and historical forces played a part in development.

(http://jan.ucc.nau.edu/lsn/educator/edtech/learningtheorieswebsite/vygotsky.htm)

In brief, Vygotsky's work is centred on the social dimension of learning at the Application, Analysis and Evaluation stages in the Cognitive Process Dimension. Vygotsky's framework is relevant from a social aspect and plays a key role in this research as much of it entails collaboration between learners. In essence, he recognised that learning always occurs and is inseparable from a social context (learners learn from each other) and as a result, teachers often take the role of facilitators, who, within the learning environment develop learning communities (or collaborative learning groups). Following Vygotsky's framework for learning (Vygotsky, 1978), a teacher would be swayed towards instruction in support of joint tasks, challenging group work and other activities where the facilitator manages socratic dialogue in order to promote deeper learning through critical thinking. Vygotsky argued that,

> *"language is the main tool that promotes thinking, develops reasoning, and supports cultural activities like reading and writing"* (Vygotsky, 1978).

In essence, learning always occurs to a greater or lesser degree when discussion and collaboration takes place involving student-student or expert-student collaboration. The words "to a greater or lesser degree" have been used because, based on Vygotsky's framework, the tasks given to learners *"build on each person's* *language, skills, and experience shaped by each individual's culture"* (Vygotsky, 1978, p. 102).

Note: With reference to Vygotsky's framework and his publication of 1978, (I), the researcher is able to relate to the cohort of learners on which this research is based. Our Engineering courses at a post 1992 University are multicultural and diverse in that they consist of a range of cultures, social and ethnic groups. At least 30% of our learners are from overseas. In conducting research using a collaborative style framework the researcher can choose to group learners, specifically by selection of individuals that have already gravitated or socially integrated with each other. Alternatively, the researcher can group them in accordance to their cultural and educational backgrounds. It is therefore recognised that on this basis, the degree of learning will differ, depending on the extent of social interaction and comfort that already exists within groups.

It can also be claimed that Vygotsky's work does not take into consideration group 'balancing' in cases of collaborative learning, which in itself can hinder the level of group achievement. Team balancing can be optimised by considering the psychometrics of each team member and balancing the team accordingly in order to improve team effectiveness (Belbin, (1993, 2010); Henry & Stevens (1999)). Although Belbin's work falls outside the scope of this research, it is proposed that it be considered for future work.

2.2.3 Knowles and adult learning

Malcolm Knowles was an American practitioner and theorist of adult education who defined andragogy as 'the art and science of helping adults learn' (Zmeyov, 1998).

Malcolm Knowles who is associated with adult learning, or andragogy, which is defined as the 'art and science of helping adults learn' (Knowles, 1984). The five principles of andragogy are that:

- As a person matures they become more self-directed
- Adults have accumulated experiences that can be a rich resource for learning
- Adults become ready to learn when they experience a need to know something

- Adults tend to be less subject-centred than children; they are increasingly problem-centred
- For adults the most potent motivators are internal.

In Knowles, (1980) six assumptions associated with adult motivation for learning are documented in brief single words. These are:

- Need to know
- Foundation
- Self-concept
- Readiness
- Orientation
- Motivation.

These will be elaborated on further within this chapter.

Fry et al., (2003) claim that there is lack of evidence to support these views but despite this it has been quite influential in teaching and learning.

There are many 'types' of learning that are much used and discussed in higher education, including experiential learning, student autonomy in learning and self-directed learning. These belong to traditional adult education along with other terms branded in higher education such as student experience, supporting students and widening participation – all with origins in adult education.

Knowles's work is acknowledged in this research but does not differentiate between the learning attitudes of subject groups or focus groups nor does it quantify their degree of willingness to learn. For example, how is the 'need to know' quantified between two individual adult practitioners, one with a passive need to know as a technical manager with a team of subordinate specialists and the other a specialist practitioner who faces repercussions by not knowing. Also, how does the 'need to know' relate to 'motivation'? How is motivation quantified? As another example, the assumption of 'readiness' to learn is very broad. How is this related and quantified to age and maturity of the individual learner?

There are weaknesses in Knowles' work in that assumptions were made but not based on empirical research. As such, it is not a theory (Curzon and Tummons, 2013)

Part of being an effective educator entails an understanding of how adults learn best. Andragogy (as based on adult learning theory) holds a set of assumptions about how adults learn and emphasises the value of the process of learning. It uses approaches to learning that are problem-based and collaborative. It also emphasises more equality between the teacher and learner. The origins of this belief were founded on the basis of the relationship that Knowles maintained with his father from a young age. His father was a veterinary practitioner who spent considerable time travelling to farms and ranches. Knowles had commented that, as a child, he had accompanied his father frequently from a young age and during their travels they had engaged in discussion on a very diverse range of subjects during which he felt that his father had spoken to him almost as an equal and never as an inferior. Quoting Knowles,

> *"we engaged in serious discussions about all sorts of subjects, such as the meaning of life, right and wrong, religion, politics, success, happiness and everything a growing child is curious about"*

Although adult education theory and concepts had preceded Knowles by many theorists, practitioners of adult education, psychologists, philosophers, socialists and educators of different countries, it was Malcolm Knowles who had created the fundamentals of andragogy as a theory of adult learning.

Knowles's theory is based on adult learning (andragogy) and advocates that adults are self-directed and expect to take responsibility for decisions. This is fundamental in Higher education and particularly in the application of a framework for this research. This is because certain assumptions are made which (in the researcher's opinion and supported by Knowles) must be emphasized or reminded to learners. The first of these assumptions is that adults (and the researcher commonly classes an adult as a learner within Higher Education or 18 plus),

Assumption 1

Have a need to know why they need to learn something – if this unclear to undergraduates, they often raise it as a question. If not questioned by the undergraduate learner and left to their discretion, they may often express eventual disgruntlement. As an example of this, students at the University of Huddersfield are given end of year module specific feedback questionnaires. One of the questions refers to the relevance of the module content to their course and career. At that particular age it is probable, but not inevitable, that they have pre-conceived ideas about future roles within a professional, employed role i.e. A student on a Batchelor's course in Automotive Engineering may envisage themselves as say, a car designer, of all things functional on a vehicle, or specifically, such as the engine. The Batchelor's courses are fully accredited and as such students follow a diet of approved modules and subjects. An undergraduate may not immediately see the relevance of say, Manufacturing Technology (where they learn about particular production processes) or Professional Studies (where they may learn about the ethical issues in automotive engineering, such as safety and emissions). They may therefore need to be informed as to why they need to learn something which may also need to be put into context.

Assumption 2

They need to learn experientially – This requires practical applications, active experimentation and the opportunity to learn by mistakes. Or at least building on past practical experiences that they can relate to. A simple example of the latter is in attempting to instruct learners on how to systematically formulate an assembly drawing (a technical graphical means of communicating how a set of parts fit together). Most have some experience in having assembled flat-packed furniture so are able to relate to this as experiential learning. We therefore go through the step-by-step process of how they have gone about it and what mistakes they may have made, how instructions could have been better and then relate this to an engineering assembly drawing (building knowledge based on constructivism theory, also see Fry et al., 2003). This example has a dual impact in that it also addresses the 'need to know' assumption. Mentioned earlier in this chapter, was that some HE institutions already provide a wider experiential learning experience (see https://nmite.org.uk/new-university-to-abandon-lectures-and-charge-12000/ and earlier example in this chapter). Chickering, (1997) rightfully reports on the traditional long standing delivery by Universities, which emphasises analytical, reflective and theoretical studies and neglects the following, despite that they have been long standing:

- Concrete experiences
- Practical applications
- Active experimentation.

Quoting Chickering,

> *'The learning cycle of concrete experience, observation and reflection, abstract conceptualization, active experimentation, and application holds promise of improving the substance of higher education'.*

This statement underpins our research.

A small proportion of learners on our undergraduate degree courses undertake study on a part-time basis as they are sponsored by their employer. Their prior experience of education was in Further Education where courses are often more practical and skills based. Such learners not only show signs of greater maturity, they are also more accustomed to experiential learning, through their everyday employed roles. They also already have an appreciation of the 'need to know' assumption of adult learners.

Assumption 3

Adults approach learning as problem-solving – This is, especially, (and should be) an assumption that refers to undergraduate engineers as they are required to be problem-solvers. This, in the researcher's opinion, also substantiated by feedback from engineering employers, should be at the heart of engineering education.

Assumption 4

Adults learn best when the topic is of immediate value – This would imply that if knowledge was provided with a purpose to resolve a known problem or task then learners would be far more receptive to acquiring that knowledge. This was successfully demonstrated in Sherwin and Mavromihales (1999) (and as discussed earlier on Background and Narrative). This also applies in situations where learners can see the value to their job or personal life. The focus of this is often on the process and less on the content being taught and considers case studies and simulations. The consideration is ABL, GBL and PBL (Problem or Project Based Learning). Andragogy can also be applied for adult learning in ‘soft skills’ domains for management development with examples in role playing for interview training techniques, dealing with grievances, being persuasive, etc.

Further to the four listed assumptions and of interest to the framework, Knowles’s advocacy lies in informal adult education and self-directed learning.

It is noted that Knowles’s research was done with white, middle-class Americans, therefore on learners which were far removed from the research environment in which we are operating.

In recognition that not everyone learns in the same way Fry et al., (2003) draw on research specific to students in Higher Education with some aspects of adult education, under the general theme of developing practice. A key point of reference to HE learners is that some are less mature students (in age and behaviour) therefore evidence and practice for ‘adult learners’ is less robust if applied as a ‘cure for all’.

Fry et al., (2003) explore interaction of students to learning tasks with a resolve of either deep approach to learning or a surface approach to learning. In the former, a learner’s engagement with a subject drives them to understand and seek meaning by relating concepts to existing experience, distinguishing between new ideas and existing knowledge. In the process they are critically evaluating and determining key themes and concepts. Their intension is to gain maximum meaning from their studies though high cognitive processing throughout learning.

In the surface approach to learning, the intension is merely to complete a task, memorise information without putting it into context. There is no distinction between new ideas and existing knowledge. This is known as rote learning. The origins of deep and surface learning are noted as part of the work of Biggs, (1987) and Ramsden, (1984).

The approach to learning by the student is not entirely down to the individual but something between the student and the task (therefore both personal and situational) (Biggs, 1987). Biggs, (1987) also identified a third approach to study – the strategic, or achieving approach. The emphasis here is specifically organisation of the individual to achieve a high examination grade. Even a learner with a usual deep approach may adopt some techniques for a surface approach with the objective of meeting the requirement of a specific activity or test. An example would be where the learner can anticipate a high score on basis of just recall. According to Fry et al., (2003), many undergraduates enter higher education under the misconception that they are entering an educational system that simply requires them to 'bank' new knowledge to their existing store.

Biggs has also defined his own taxonomy along the lines of Bloom's. Biggs's SOLO (Structure of the Observed Learning Outcome) taxonomy can be used as a framework for classifying learning objectives and student achievement and like Bloom's taxonomy; it can be aligned and is primarily concerned with the cognitive domain. The SOLO taxonomy is a hierarchical classification in which each level is the foundation for the next.

Another learning style worthy of consideration is that of Honey and Mumford, (1982). Four classifications are offered (Fry et al., 2003):

- Activists – who respond most positively to learning situations offering challenge, to include new experiences and problems, excitement and freedom in their learning.
- Reflectors – respond most positively to structured learning activities where they are provided with time to observe, reflect and think, and allowed to work in a detailed manner.
- Theorists – who respond well to logical, rational structure and clear aims, where they are given time for methodical exploration and opportunities to question and stretch their intellect
- Pragmatists - who respond most positively to practically based, immediately relevant learning activities, which allow scope for practice and using theory.

It is however anticipated that for any individual there may be elements from two or more of these four categories.

2.3 Experiential learning

Experiential learning or 'learning by doing' recognises that experience gained through life, education and work, collectively play a central role in the process of learning. The most popular theorist on learning through experience is probably Kolb, (1984). In engineering education and training experiential learning can be appreciated in its wider context alongside examples of practice such as:

- Work-based learning and placement learning
- Teaching laboratory and practical work
- Action learning
- Role play

as well as many types of small group teaching.

There are many forms of the Kolb model frequently encountered. It is adapted to accommodate specific types of learning (or training) experiences and alternative terminology is used. Experiential learning is based on the notion that understanding is not fixed but cyclical and based on experience. Therefore, understanding changes (formed and re-formed through experience) is a continuous cyclical process. In Kolb's four stages (Concrete experience, Reflective observation, Abstract conceptualization and Active Experimentation) all stages are necessary for effective learning to be achieved.

Table 2.1: Learning styles (based on Wolf and Kolb, 1984), reproduced from (Fry et al., 2003)

Learning Style	**Strengths**	**Dominant Learning Ability**
Convergent	*Practical application of ideas*	*Abstract Conceptualization & Active Experimentation*
Divergent	*Imaginative ability and generation of ideas*	*Concrete Experience & Reflective Observation*
Assimilation	*Creative theoretical models and making sense of disparate observations*	*Abstract Conceptualization & Reflective Observation*
Accommodative	*Carrying out plans and tasks that involve them in new experiences*	*Concrete Experience & Active Experimentation*

Wolf and Kolb (1984) suggested that learners develop their own styles that highlight modes of learning in preference over others. These are shown in table 2.1 and indicate to us that as those responsible for facilitating education we are responsible for catering for different learning styles. The preferred learning style of an individual may have a relationship to the particular disciplinary framework in which learning is taking place. By classifying academic knowledge in accordance to discipline would suggest that a preferred learning style might be attributable to a particular discipline framework.

Table 2.2 shows the four classifications of academic knowledge and how learning styles are closer linked to discipline.

Table 2.2: Classification of academic knowledge. Based on Kolb-Biglan Model described by Becher (1989). Reproduced from (Fry et al 2003)

1. Abstract Reflective *AC-RO* *Hard Pure* *Natural Sciences* *Mathematics*	*2. Concrete Reflective* *CE-RO* *Soft Pure* *Humanities* *Social Sciences*
3. Abstract Active *AC-AE* *Hard Applied* *Science-based professions, Engineering, Medicine and other healthcare professions*	*4. Concrete Active* *CE-AE* *Soft Applied* *Social professions* *Education, Social Work, Law*

Fry et al., 2003, observe that reflection on practical experience is central to the development of professionals. Distinct 'artistry' in one's field, or a high level of expertise, cannot be learnt through conventional teaching models as it requires observation of competent practitioners, experience in carrying out an extensive range of specialist tasks in one's job and reflecting upon practice. This would follow Kolb's pattern of conceptualization and reconceptualization as part of a continuous process. A key aspect of lifelong learning is therefore the development of reflection as part of learning, state Fry, et al., (2003) but there are difficulties inherent in developing reflective practice.

2.4 Bloom's Taxonomy and revisions of it (by Krathwohl and Anderson)

Bloom's Taxonomy of Learning Objectives

The Taxonomy was originally proposed in 1956 and identifies six learning objectives and classifications of educational goals. The original six learning objectives were:

- Knowledge (remember)
- Comprehension (understand)
- Application

- Analysis
- Synthesis (create)
- Evaluation.

These are illustrated in figure 2.1.

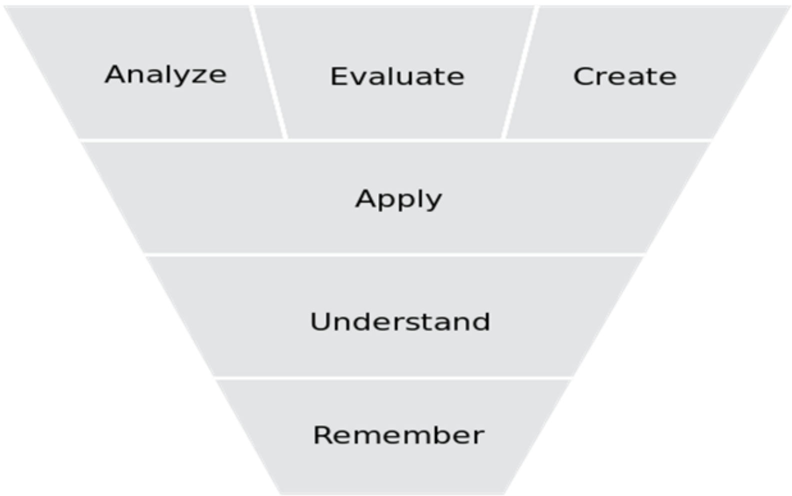


Figure 2.1: Categories in the cognitive domain of Bloom's Taxonomy, reproduced from (Anderson & Krathwohl, 2001)

The cognitive domain involves knowledge and the development of intellectual skills (Bloom et al., 1956). These six categories (as shown in figure 2.1) include recall or recognition of key facts, procedural patterns and concepts that serve in the development of intellectual abilities and skills. Each category can be thought of a further degree of difficulty and therefore the early ones are prerequisites to the later ones. As such, these have normally been mastered before the next ones take place. Figure 2.1, the researcher believes, is a misleading representation because where engineering education is failing many graduates and engineering employers today, is that this diagram would more correctly illustrated inverted, in that the base would be broader than the top (crest). It would more close resemble a pyramid with the top three categories of cognition (Analyse, evaluate and create) be either very limited or absent.

Bloom’s original Taxonomy was published in 1956 (Bloom et al., 1956) and a revision of the original framework was developed 45 years later (Anderson, Krathwohl, et al., 2001) and referred to as the revised Taxonomy.

Discussions by a group of educational academics led to an agreement that such a theoretical framework is best obtained by classifying goals of the educational process. This is because it was recognised that educational objectives provide the basis for curricula development and testing. This is the starting point of much educational research and also forms the basis for defining the framework of research objectives. (Bloom, Benjamin S., 1994). However, it is noted that this work is not based on empirical research.

Bloom’s Taxonomy classifies different learning objectives and divides educational objectives into three ‘domains’,

- Cognitive: mental skills (knowledge)
- Affective: growth in feelings or emotional areas (Attitude or self)
- Psychomotor: manual or physical skills (Skills).

These are sometimes loosely described as knowing/head, feeling/heart and doing/hands respectively. Within these three domains, learning at a higher level is dependent on having achieved prior knowledge and skills at a lower level (commonly referred as prerequisites). Bloom’s work is considered to be a foundation and essential element within the educational community. Bloom had declared his book to be *‘one of the most widely cited books in American education’*, (as evidenced in the 1981 survey:’ Significant findings that have influenced the curriculum: 1906-1981’, by H.G. Shane and the 1994 yearbook of the National Society for the Study of Education). Bloom’s Taxonomy is considered to be the foundation and an essential element within the educational community.

A goal in applying the Taxonomy is to motivate focus in all three domains – categories of learning (Cognitive, Affective and Psychomotor) creating a more holistic form of education. This is particularly important in vocational education such as in Engineering and Technology associated subjects. Cognitive and Psychomotor domains are relatively easy to identify and define (especially in the form of learning outcomes) for engineering education. This is not so with the Affective domain, but as the researcher intends to consider this as part of framework, the researcher shall attempt to briefly define it with reference to what is understood of it and its relevance to this work. The Affective Domain is concerned with feelings and emotional areas of learning. As the researcher interprets this, he considers it to be evidence in the work from feelings of expressions by learners, of say:

- Confidence
- Self-esteem
- Fulfilment in learning
- Fun and enjoyment during the process of learning
- Socially belonging
- Sense of purpose with positive conviction
- Positive feelings about course of study
- Willingness to learn.

These feelings of expression are not clearly identified and specified by Bloom, but simply referred to as being concerned with feelings and emotional areas of learning.

Bloom had considered his initial effort in defining the Taxonomy as a starting point that required further adaptation in accordance to the field of educational application, this being stated in a 1972 memorandum,

> *"Ideally, each major field should have its own taxonomy in its own language – more detailed, closer to the special language and thinking of its experts, reflecting its own appropriate sub-divisions and levels of education, with possible new categories, combinations of categories and omitting categories as appropriate".*

Hence its adaptation to the UK-SPEC for engineering educational objectives and outcomes. This work is a further refinement of the objectives with the aim of creating a more holistic form of engineering education.

David Krathwohl had co-authored with Bloom and later revised the taxonomy along with Lorin Anderson (Anderson and Krathwohl, 2001).

The Taxonomy was revised to contain verbs (Anderson, 1994 & 2002 – see figure 2.2) and has been adapted to be at the core of engineering education (Krathwohl,

2002) to form the UK-SPEC (Standard for Professional Engineering Competence) for monitoring learning outcomes. The measurement of these outcomes is largely a qualitative process. UK Engineering education focuses on delivering these outcomes. Here the researcher explains how the revised taxonomy differs from the original and the significance to the framework employed. In the original taxonomy the Knowledge dimension contained three instead of four categories with subcategories for each. The revised new taxonomy used a fourth category known as the Metacognitive Knowledge (which was not widely recognised at the start of the original development). The Metacognitive involves knowledge about cognition but also about awareness of one's own cognition. It is important in that it enables students to be aware of their metacognitive activity and being able to use this knowledge to adapt the ways in which they think and operate. So for the knowledge dimension alone, the revised taxonomy of Metacognitive Knowledge (knowledge of cognition in general as well as awareness and knowledge of one's own cognition) contains the following sub-categories:

- Strategic knowledge
- Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge
- Self-Knowledge.

The relevance of the fourth dimension of the revised taxonomy to the framework used is in that the researcher is introducing it though the ICEE examples where students are required to apply knowledge gained through more than one module by putting it into context within a practical activity. In Sherwin and Mavromihales, (1999) this was demonstrated once learners had realised the final performance of their designs as compared to the theoretical design. The metacognitive sub-category therefore serves as means of closing the learning loop, through awareness.

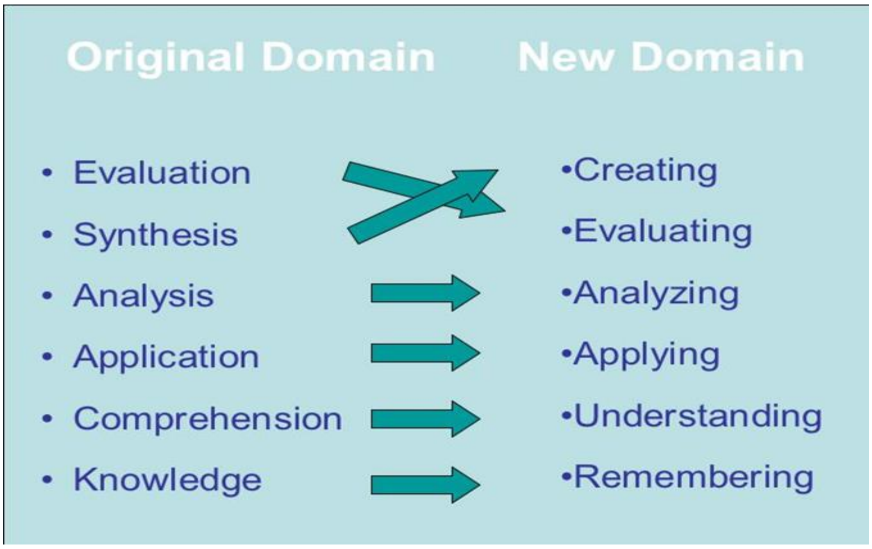


Figure 2.2: The domains as identified in the original taxonomy and their revision (note: original domain nouns are changed to verbs). Reproduced from Anderson, 2002.

Lorin Anderson's revised taxonomy (figure 2.2) reflects a more active form of thinking and can be more closely associated with the subject area of Engineering and Technology and more specifically in modules such as Engineering Design, Applications of CAD/CAM and Manufacturing Technology. A higher order domain of cognition is anticipated to be achieved through ICEE.

A more detailed representation of Bloom's revised taxonomy of learning domains with verbs can be seen in figure 2.3.

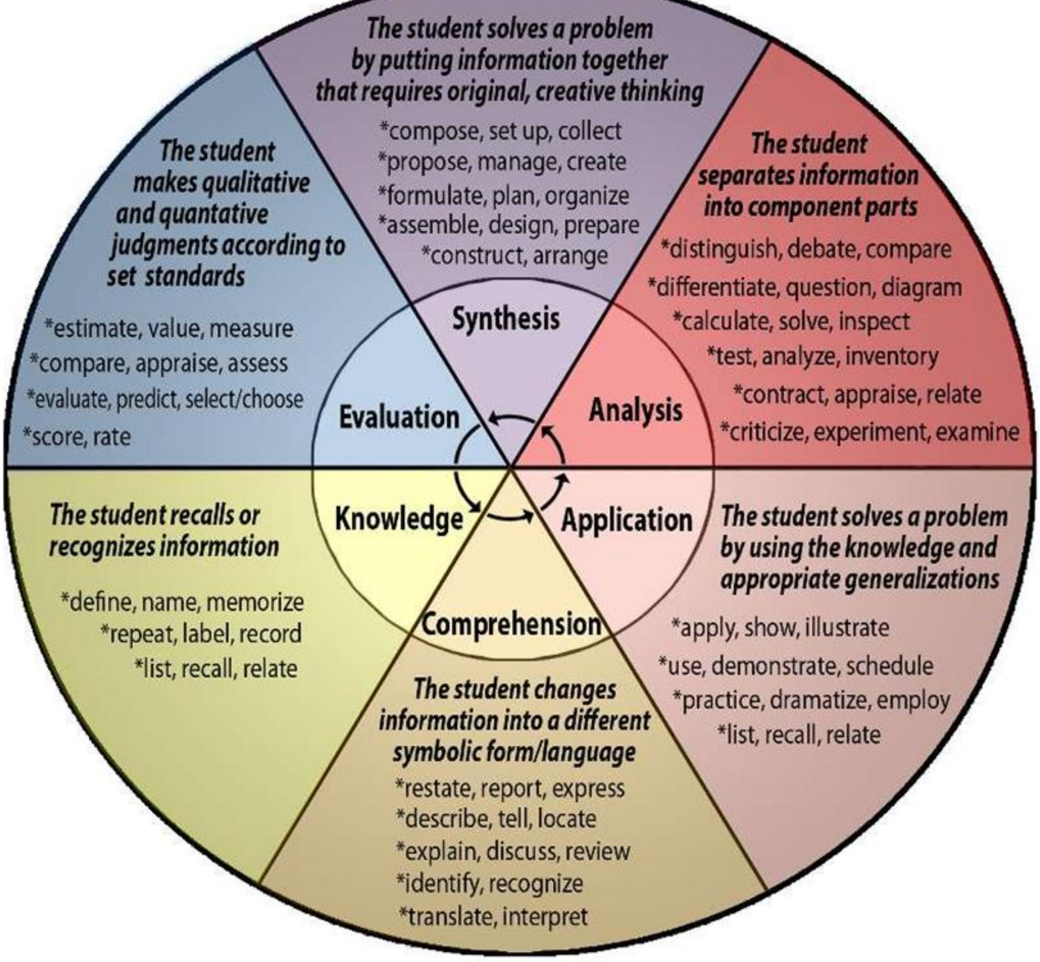


Figure 2.3: Bloom's Taxonomy with Verbs. Reproduced from Google images. URL: https://www.google.co.uk/search?q=bloom%27s+taxonomy+verbs&tbm=isch&source=hp&sa=X&ved=2ahUKEwjnip2JqKLgAhVvQxUIHXeEBg4QsAR6BAgFEAE&biw=1366&bih=628#imgrc=2yj0PJxpY4HR_M: [Accessed 4/2/2019]

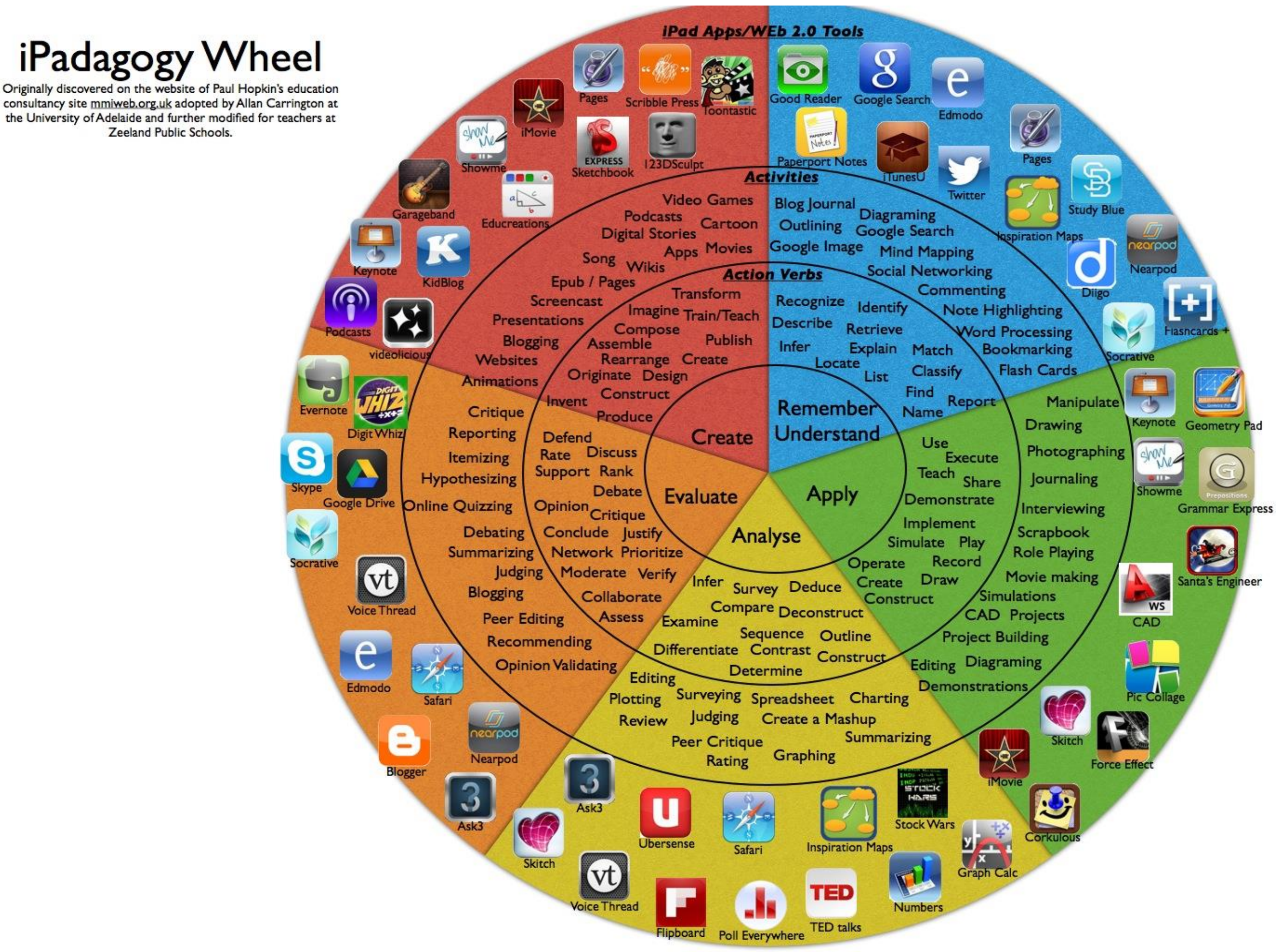


Figure 2.4: Bloom's Taxonomy with verbs, in compliance with e-Learning interventions, for today's learner. Reproduced from Google images, URL: https://www.google.co.uk/search?q=bloom%27s+taxonomy+verbs&tbm=isch&source=hp&sa=X&ved=2ahUKEwjnip2JqKLgAhVvQxUIHXeEBg4QsAR6BAgFEAE&biw=1366&bih=628#imgrc=IIPKAkz0jridzM: Accessed 4/2/2019

In Anderson (2002), the subject of curriculum re-alignment is discussed where it is strongly argued, with supporting research, that a re-alignment is required with strong links between objectives of learning and assessment, between objectives and instructional activities and materials and between assessments and instructional activities and materials. ‘Curriculum alignment’ can be explained by considering content validity, how the content is covered, and opportunities to learn. All of these require addressing for ‘curriculum alignment’. Anderson states that, based on documented cases, there have been few analytical frameworks in existence for making sense of the data from curriculum alignment studies. Anderson makes a strong case for the requirement of such frameworks through several case examples. He quotes the work Cooley and Leinhardt, (1980) which poses questions such as to determine the percentage of students taught the minimum material needed to pass an item such an examination. In Anderson’s opinion, one of the most comprehensive frameworks in regard to this was developed by Nystrand et al., (1997) which relates to general areas of mathematics divided into 7-10 specific topics and six levels of “cognitive demand”. Anderson’s curriculum alignment is illustrated in figure 2.5. It emphasises, through supporting studies, which content coverage and opportunity to learn must relate to instructional activities and materials with assessments (side C of the triangle in figure 2.5. My view is that this ‘curriculum alignment’ focusses on learning for assessment rather than higher order learning for synthesis (creativity) as is required for engineering undergraduates.

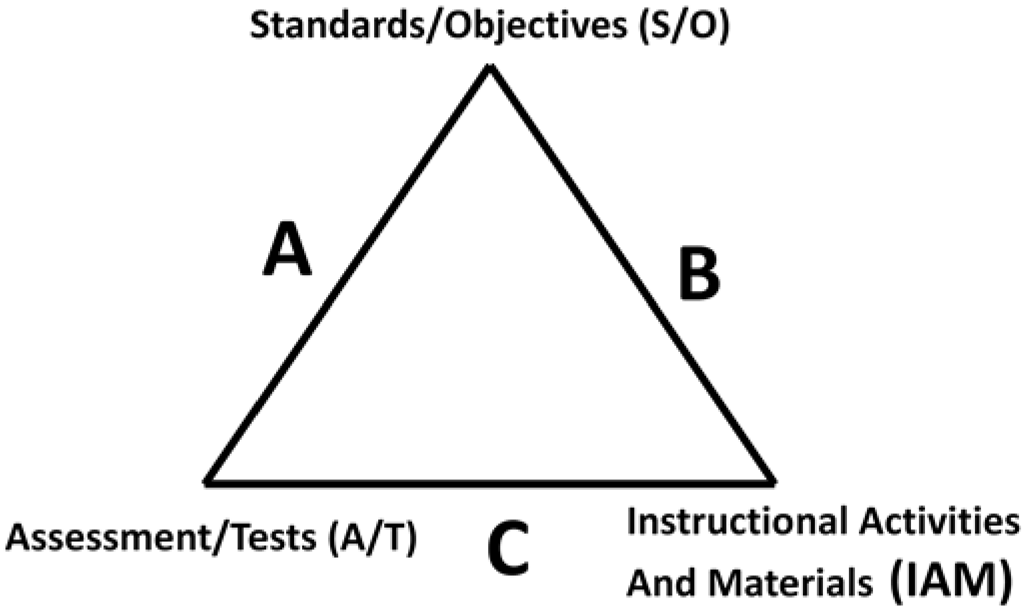


Figure 2.5: Relationship amongst Standards/Objectives, Instructional Activities and Materials, and Assessments/Tests. Reproduced from (Anderson, 2002)

Unlike the work of Anderson (2002) and Cooley and Leinhardt, (1980), John Dewey's educational philosophy was based on pragmatism. He advocated that people learn though a 'hands-on' approach, which is partly what this research is based on and the basis on which new paradigm shifts in engineering education (as previously discussed and cited) are based. Pragmatic learning implies that learners must interact with their environment in order to adapt and learn. This is especially the case with vocational engineering course, however, at undergraduate level it is the researcher's belief that effective learning and higher order thinking (in accordance to Bloom's revised taxonomy) requires an instructional educational framework of blended techniques. That forms the basis of case studies covered as part of this research investigation. Experiential learning was previously discussed and is in alignment with Dewey's pragmatic and 'progressive education' pedagogical movement. It is the basis for various educational programs such as:

- Activity Based Learning
- Project Based Learning
- Practical Problem Solving and Critical Thinking
- Entrepreneurship in education
- Collaborative and Cooperative learning.

According to Dewey, the study of the core subjects (in the case of mechanical engineering undergraduate studies would include, mathematics, mechanical science and professional studies, as examples) should be coupled with the study of practical applications of manual training. The latter is fundamental to the framework used as part of this research.

Robert Gagné's theory of instruction is also of note for its great influence on curriculum development and delivery. This has later been adapted for application to serious educational game design, as a means of providing a sort of check list. Gagné's theory of instruction consists of three branches. The first is the taxonomy of learning outcomes, as previously described and based on Bloom's revised taxonomy (Cognitive domain, Affective domain and psychomotor domain). Secondly are the conditions of learning and the third are the nine events of instruction. These are diagrammatically illustrated in figure 2.6.

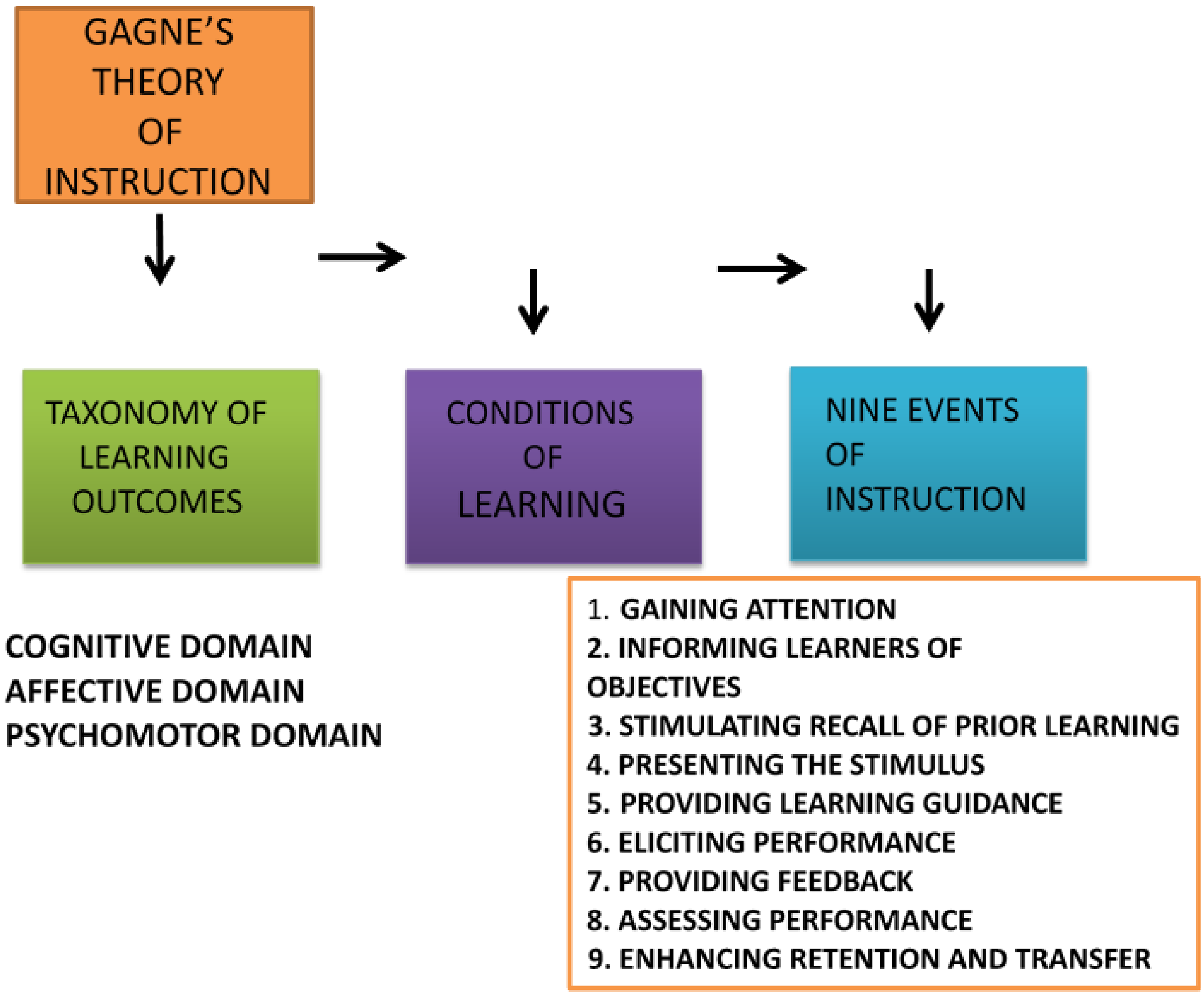


Figure 2.6: Gagné's three branches of instruction.

Gagné’s instructional theory appears to be an attempt to integrate a range of existing frameworks of learning and instruction (from other perspectives) into a more all-inclusive theory of instruction to good effect and with impact.

2.5 Constructivism

Of the most prominent schools of thought on how we learn is constructivism and this is what contemporary psychologists base their theories to explain how learners learn. The idea of this hinges on that a continuous building (construction) or amending process of previous structures takes place. This is provided that new experience, actions and knowledge are adjusted and accommodated in the brain. This is a process of transformation which may be effect one or more of the domains (cognitive, affective, interpersonal or psychomotor) is actively constructed by the individual. (Piaget, 1950) and (Bruner, 1966) are two of the 20th century’s most prominent constructivists. The researcher is able to draw on Bruner’s ideas because his ideas relate to modes of thinking for individual disciplines and his notion of revisiting knowledge at ever-higher levels of understanding. Most current ideas about student learning such as experiential and the use of reflection are based on constructivism. It states that that we learn by accommodating new understanding and knowledge in to existing, extending and replacing old knowledge and understanding. With reference to the teaching practitioner’s role in HE, we must be aware that we are rarely ‘writing on a blank slate’, however rudimentary or incorrect pre-existing related knowledge and understanding are. So although we may think that of learning in terms of adding more knowledge, we need to consider how to make transformations of learners’ pre-existing knowledge.

Another school of thought is social theory (Lave and Wenger, 1990) otherwise known as situated learning. It focuses on learning in context where the learner engages with others to develop/create collective understanding as part of communal practice. Learning is thus viewed as a social practice. A view shared by many others. There have been other researchers who have developed theory of situated learning such as Brown, Collins and Duguid, (1991) who emphasised the idea of cognitive apprenticeship by stating that, *“Cognitive apprenticeship supports learning in a domain by enabling students to acquire, develop and use cognitive tools in authentic domain activity. Learning, both outside and inside school, advances through collaborative social interaction and the social construction of knowledge.”*

2.6 Review of e-Learning and blended learning articles

Progressive methods of teaching and learning with a focus on e-learning have been published (Salmon 2010) and distinct delivery methods described (Clifton and Mann, 2011, Holmes and Gardner, 2008, Gupta, 2008). All these studies are conducted as Action Research by practitioners in Higher Education with students from nursing and technology, amongst other. In Salmon, (2010) a five-stage model or learning scaffolding is applied to three case studies to enable groups to work together remotely using asynchronous ‘bulletin’ boards (see figure 2.7). The case studies on which this study was based were on disciplines of archaeology, digital photography and media and communications. It is claimed to be applicable to wide range of other disciples to include the sciences and practice-based subjects such as nursing and management. Activities and artefacts were developed for students and tutors in order that they are able to interact in groups. Learning experiences and engagement were studied using qualitative methods on a more informal than formal basis and cognitive mapping was used to determine changing views, feelings (mood and emotion) and experiences of the learners. The five-stage model has been explored by Salmon in other examples in blended teaching and learning. Although the five-stage model as documented for the given cases, dates back to 2010, it serves well for asynchronous interaction and conferencing, (more so in today’s world where learners are able to learn anywhere and anytime). However, the deployment of wikis and blogs is now widespread. Within the HE sector this is usually facilitated within VLEs (Virtually Learning Environments) such as Blackboard and Brightspace. The five stages of the model for teaching and learning online demands most activity at the first stage (access and motivation) when the system is being populated, set-up, accessed after training has been provided. The proceeding stages entail the establishment an identity and familiarity with each other, receiving and giving beneficial information and later stages entail more constructive and collaborative engagement, which eventually leads to individual application of learning.

Asynchronous learning can work well with today's learners but it can also be prone to failure, based on the maturity and motivation of the learner. Young adult learners are often accustomed to using their own social software application such as Facebook and WhatsApp, provided they are motivated and can see a purpose to do so. In Salmon's study, the students were engaged on a voluntary basis so motivation was almost a forgone assumption. In the ever-present learning world of today, despite the endless opportunities to learn autonomously and in an asynchronous manner, there also exists an endless stream of distractions and information overload. On this basis it can be said that the days of structured, disciplined and scheduled learning are far from becoming obsolete. Learners of today have different habits to students of the bygone in that they demand the wide range of resources to which they are socially accustomed to, a view also supported by Clifton and Mann, (2011). They also suffer from lower attention span due to distracting activities continuously offered to them. The challenge, however, in designing educational activities in virtual worlds remains. This must be considered in the design of the case studies. Social interaction is important in learning and something often overlooked when planning asynchronous learning. E-learning does not exclusively imply working asynchronously in isolation by accessing information (interactively or otherwise) from the web.

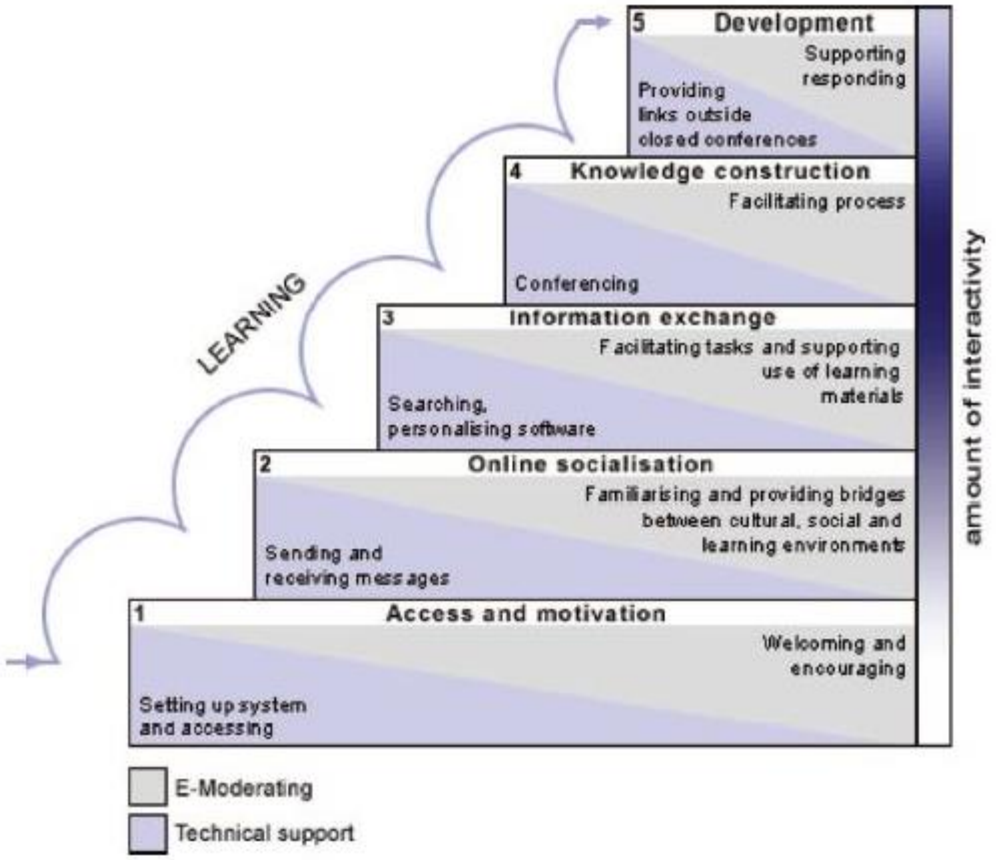


Figure 2.7: Five-stage model of teaching and learning online (reproduced from Salmon, 2004, 29)

In Clifton and Mann, (2011), the authors report on the use of YouTube for training student nurses, in support of their vocational training. The pedagogical application holds similarities to the training of undergraduate engineers. The use of YouTube is justified on the basis that it can promote critical thinking if applied correctly. It can also form a vital intervention for e-Learning in a fast shifting HE model where students have become powerful consumers demanding up-to-date interesting and interactive models of teaching and support. This Net generation (or “Digital Natives” as they are referred as by Prensky, (2001)) is native to the digital world and YouTube is familiar to them within their environment. The traditional university teaching driven by the historical pedagogical models of delivering lectures and coupled with tutorials remains at the forefront of HE. Controversially, in support of the traditional lecture lies economy of delivery, in an educational system that has gradually adopted a more business like model. It is unclear from Clifton and Mann whether relatively new technologies such as YouTube, podcasts, blogs, wikis actually produce better outcomes (despite positive responses from learners). The researcher aims to verify this through one of the case studies where he combines audio-visual aids with experiential learning, reflection within a constructivist framework.

Skiba, (2007), rejects the idea that technology is a “panacea” for the internet generation, a statement that the researcher supports as part of this research. It is important, as emphasised by the authors, that Universities support deep learning approaches in order that it can be applied in a professional world. Passive observation of audio-visual material on YouTube alone does not promote deep critical thinking. Biggs (1979) describes a taxonomy where students take a range of different approaches for deeper learning and academic success. This holds particularly as true today as it ever has done due to the array of technology on offer. In Biggs’s solo taxonomy students “relate, compare and analyse ideas in order to generalise, hypothesize and theorize”. YouTube can be used in support of these claims. Benefits such as large group teaching scenarios and increased engagement are acknowledged. In order to stimulate deep learning, students need to be encouraged to relate, compare and analyse ideas. Simply showing YouTube clips in class for students to passively watch does not allow deep learning to occur. Discussion needs to be stimulated in class by the facilitator in order to meet the aims of the session. The way this is achieved is reported in Godwin (2007) who focusses group discussion for deeper learning. Multiple viewpoints provoke critical thinking approaches and it is up to the facilitator to either present these to learners or encourage them to present their own. An important point that is highlighted by Clifton and Mann is for users to be critical evaluators of their learning material, which can be a potentially flawed, as there are no guidelines on quality and no regulation as to what is available with approval on the World Wide Web (WWW). Learning information may be biased, misleading, offer subversive advertising or be of poor quality. It is therefore up to the facilitator to filter through the vast repository for suitably recommended material. As Skiba, (2007) puts it:

> “There is a lot of controversy surrounding trash on YouTube, but this is a social phenomenon that cannot be ignored by educators”

Salmon et al., (2008), present a case of building institutional wide introduction of e-Learning. They report in some detail on the design and implementation process to allow widespread provision at a UK dual purpose University (with Teaching and Research provision). Subject groups worked in small teams with learning technologists, pedagogical facilitators and librarians. They report on improved scores from an e-Learning benchmarking exercise which resulted in increased e-learning capability on their VLE environment. It is the opinion of the researcher that, the authors have made some very valid statements and observations which are also substantiated by previous publications. This typically included the introduction of a VLE system (Blackboard, in this instance) by an IT department, but without a strategic plan for using learning technologies or deliberate revision of pedagogical approaches. In engineering terms, this can be likened to the introduction of a Computer Aided Design (CAD) system with the expectation of radical and automated changes in the design process. By failing to recognise that a CAD system is a designer's tool and not a means to automate the design process, will render the system useless and deemed to fail in achieving the required objective.

Salmon reports that the VLE was firstly embraced by early adopters and innovators amongst staff and response from students varied widely. Potential was recognised in how improvements could be achieved in teaching and learning, along with positive changes in the student learning experience and the institution set upon the implementation of an e-learning and pedagogical innovation strategy. The paper also makes reference to studies that substantiate the reluctance of some university teachers to embrace change in their pedagogy, whether associated with e-learning or other initiatives.

Prensky, (2001) presents a convincing case on why the current (traditional) educational system is no longer fit for purpose in educating the learners of today. He refers to them as "Digital Natives" who as learners have changed radically within an educational system that was not designed for them and run by mostly "Digital Immigrants". Prensky refers to the "Digital Immigrants" as the teachers, facilitators and policy makers who are older and of a different generation to the "Digital Natives", who have grown up in a digital world. The obvious differences between the "Digital Natives" and the learners of bygone eras goes deep, according to Prensky who makes a similarity to an adult immigrant attempting to learn a new language to which they are not accustomed to – the accent will always be evident i.e. the desire to print emails. More importantly, the "Digital Natives" have a brain that has developed in a different way and therefore are better able to think and process information fundamentally differently from their predecessors. Their entire lives have been spent with computer games, email, the internet, mobile devices and instant messages, all of which are integral parts of their lives. Prensky identifies this as the single biggest problem facing education today. As Prensky puts it,

> “our Digital Immigrant instructors, who speak an outdated language (that of pre-digital age), are struggling to teach a population that speaks an entirely new language”.

Preferences for the modern age learner are graphics before text, random access (sort of hypertext), function best when networking and thrive on instant gratification and frequent reward, claims Prensky. On the basis of Prensky’s work, it appears that learning through games for the “Digital Native”, makes an effective means of learning, who urges educators to think about teaching both Legacy and Future content in a manner that “Digital Natives” are accustomed. Adapting materials to the language of “Digital Natives” can be achieved successfully. “Learning new ways to do old stuff” is the way forward and this can be achieved for all subjects, at all levels, using the learners of today as a guide. It is of worthy note that Marc Prensky is a game designer in the education and learning sector. Although his observations and comments on “Digital Natives” and how they learn, have been well published and accepted by many, they remain just that, observations, and do not appear to draw on data.

Marc Prensky’s work is cited in Richard Van Eck’s paper (Van Eck, 2006). Van Eck’s work crosses the boundary between e-learning and Digital Games Based Learning (DGBL). Both authors have published landmark papers. Van Eck refers to the many publications on the powers of DGBL. Although he puts forward a good case for wider applications for almost any subject area and categorises types of games what Van Eck hasn’t given sufficient consideration and discussion to is Games Based Learning with application of Digital devices. The assumption is that, when we refer to the subject of DGBL, we are referring to all-encompassing fully digital games entirely operable or executable on a tablet, mobile device, console, Personal or Laptop Computer. Van Eck commences to make his case by firstly referring to today’s “Net Generation” or “digital natives” who have become disengaged with traditional instruction, deal well with multiple stream of information, require brief and frequent interactions with content, possess exceptional visual skills and require immediate feedback. All the characteristics that match well with DGBL. He recognises the shortfall of research that explains why DGBL is engaging and effective and especially practical guidance for, ***when, participant type, conditions of play, timing,*** and so on in order to integrate and maximise their learning potential within mainstream education. There exists, a small but limited selection, of literature that personifies well-established learning principles, theories and models. The danger exists that games are developed that may be fun and all absorbing to play but hit-and-miss when it comes to educational goals and outcomes. The answer is to find the interaction between pedagogy and engagement in educational games. There have been numerous studies over the years to confirm that games promote learning (as well as possibly reducing instructional time) across many disciplines and ages (Van Sickle, 1986, Randel et al., 1992). Although not all of these reviews include the digital medium, there is little or no reason why these reports do not hold true regardless of the medium, from a pedagogical standpoint. Van Eck states that games are effective because of what they embody (such as well-established principles and models of learning, for a good educational game) and what learners are doing as they play a game, provided that they remain within the context of the subject matter. Or what is known as situated cognition.

A number of reasons have been identified through research as to why and how games are effective learning tools and Van Eck lists some of them as follows:

- Anchored instruction
- Feedback
- Behaviourism
- Constructivism
- Narrative psychology.

There are three approaches that can be adopted in implementing DGBL, according to Van Eck:

- Have students to build them from scratch
- Have educators and/or developers build them from scratch

- Integrate commercial off-the-shelf (COTS) games into the classroom.

The first approach appears appealing with promising potential, although the researcher has not attempted this, as of date. It's appeal lies in that learners become familiar with the content (as well as potentially develop programming skills and /or game design skills) as they develop the game and as "Digital Natives" would probably offer a more creative solution in compliance to what they would consider most appealing in such a game. The second approach is time intensive and costly (typically one or two years) as it requires teams of artists and programmers. It would also tend to lack the subject specific focus unless closely guided by the educator. Although potentially regarded as the "Holy Grail" approach to DGBL, (Van Eck, 2006) it is resource-intensive and although can cross educational boundaries, most educators teach within the traditional institutional structure which does not easily allow this. The third approach is the most cost-effective whilst offering commercial standard quality in functionality. It involves taking existing games (not necessarily developed as learning games) and adapting them for the learning environment.

In the opinion of the researcher there is a fourth approach, as discussed earlier, which is GBL incorporating a digital device. One of the reasons for this, and as identified by Van Eck is that the existing higher education infrastructure is ill-prepared to support DGBL. The fourth approach that is proposed as part of this research has been overlooked by previous cited work.

A key point that can be drawn, and worthy of further consideration, is that it is critical to understand not just how games work but how different types of games work and especially how game taxonomies align with learning taxonomies.

Slevin's (2008) paper on 'e-learning and the transformation of social interaction in higher education' is a highly detailed critique of Salmon's (2000) work in which he primarily praises Salmon's pragmatic approach. Prior to his detailed critique he comments on the way in which e-learning is transforming higher education. However, much of the research work associated with it is theoretically-based whilst Salmon's hands-on approach to teaching and learning draws together developments in social, educational and communicational theory in an applied way. Theoretical developments provide concepts and frameworks for e-learning which should not, in any way, be regarded as just an alternative way of delivering information as a resource for learning. In agreement with Slevin's comment is the argument that e-learning delivery can predominantly be face-to-face or blended with a combination of face-to-face with some online interaction. Whilst e-learning has opened up new opportunities in higher education, it has also raised uncertainties. So whilst Slevin aims to elaborate on conceptual issues associated with e-learning and how they translate into theory and practice, he uses Salmon's work as case examples, noting that success in e-learning is patchy and success stories usually arise from the "ground up" effort of individuals rather than "Concerted effort of an organization geared to deliver excellence". Misunderstood interactional impact of e-learning media results in VLEs being treated as no more than efficient technological means for storing, distributing and retrieving lecture handouts and assignments. In an upbeat support of Salmon's work, he comments how e-learning can be more than a tool and more of a social space for discussions, construct networks and "development of respect in regard of different opinions and arguments". Such an approach uses a constructivist approach to learning, fostering deeper thinking and reflection.

The issue of increasing student support whilst also improving retention in HE has been addressed by means of an action research project in HE by Hughes, (2007). A blended learning approach is reported in which different cohorts of students on an undergraduate education module are compared for retention and attainment. Interventions are introduced for one cohort whilst they are not for others and the results are compared. Historically, the module suffered from high drop-out rates which were as high as 30%. The issue of retention is one that has gradually moved to the top of the agenda for many universities, over several years. This is because of the wider access to HE and recruitment from diverse backgrounds (both culturally and economically) whilst it is acknowledged that students from poorer backgrounds are more likely to withdraw from their course. Hughes, (2007), cites a range of reasons for poor retention. Retention, as has been found, cannot be entirely 100% as there will always be an inevitable proportion of students who due to reasons relating to personal resilience, personal identity factors, lack of support networks, poorly presented courses, poor individual support or too challenging. Sometimes, students from non-traditional backgrounds feel that they do not belong.

The matter of what can be done without compromising standards is a difficult one for many institutions. There is evidence that attrition rates are higher for courses delivered entirely online via distance learning as compared to campus delivery (Simpson, 2003, 2004). Campus delivery is certainly not without its retention problems but there are lessons to be learnt from distance learning, in reference to effective learner support (Tait, 2004). In Hughes, (2007), aimed at improving retention at module level through blended e-learning with classroom teaching with the consequence of reducing face-to-face contact time whilst increasing tutor support in order to target 'at risk' learners. It would appear that a growing body of research supports the view that due to lack of socially constructed environments, online learning can disadvantage learners. Hughes and Lewis, (2003), demonstrated that campus delivered courses with online components can lead to a positive learning experience. However, this has to be well prepared and supported claim the authors, who indicate the need for greater time at the earlier stages of the module. Several observations are made by Hughes, (2007), with regard to blended learning interventions. The interventions included greater use of the VLE for online learning material to support the class delivery, more frequent collaborative tasks and formative assessment and feedback as well as informal/social interaction amongst learners. The result was that a significantly larger proportion of students had submitted work (94% as compared to 75% for a non-targeted group) and the fail rate was also significantly different (6% as compared to 25% for a non-targeted group). Highes concluded that more time was required at the beginning of the module so the module became 'front-loaded' especially in aspects such as technically supporting students who had never used a VLE. This approach therefore requires staff that is conversant with the technical aspects of a VLE and therefore able to facilitate the both online learning as well as peer-to-peer support without being intrusive. Less experienced and untrained staff would struggle with achieving this. The results of Hughes, (2007), may lack accuracy as, in my opinion, the differences between cohort sizes for the group with interventions was small (15 learners) as compared to the other groups of in excess of 20 learners. Such small group sizes are inadequate for validating. We may therefore not be confident about Hughes findings on the basis of sample size which does not convey a positive effect due to interventions. Hughes provides little detail as to the profile of the learners which were the subject of the research.

2.7 Review of Electronic Voting Systems (EVS) and e-learning articles

The use of Electronic Voting Systems (EVS) is reported by Read, (2010). This is a short article that accounts on the positive experience of educators that have used such systems and encourages their wider use. Although quite factual in presenting largely anecdotal evidence the paper identifies the need for evaluating the impact of EVS technology on student learning, quantitatively. This is in the face of some scepticism. Such systems are primarily built on the presentation of multiple-choice questions to learners, who select an answer using a voting pad (frequently referred as a clicker). One of the key reported benefits, lie in identifying which elements of the topic require revisiting. Educators are sometimes deterred from using such systems on logistical grounds rather than pedagogical grounds. Equipment and software can be cumbersome to use therefore the user may be discouraged following a bad experience. It should however, be noted that, this article was published in 2010 and systems have progressed in development, for ease of use, robustness and functionality, since then. Certain shortfalls remain in that EVS systems, in general, do not accept numerical or free-text answers and when they do (for example, Socrative and TurningPoint) there are significant limitations, in my opinion. A common criticism is that such systems simply test recall. However, from own experience, the educator can go a long way in overcoming this through the phrasing of questions that require for the correct answer to be deduced though reasoning and logic or scientific explanation. This helps promote higher-order cognitive skills rather than just recall. Some of the case studies reported upon later, demonstrate this, as well as determining whether EVS can quantitatively improve the performance of learners, in assessment. The article is in agreement with the researcher in that such systems are an asset in that they allow the educator to provide instant feedback and to rapidly correct misconceptions. As in the earlier reviews of e-learning, the true value of educational technology for supporting teaching and learning lies in the creativity and skill of the educator taking charge to integrate within the process of delivery of education. This is not only my opinion but is extracted from the review of the work of Salmon et al., (2010). E-Learning therefore calls for a range of new skill sets from the educator, otherwise will be prone to failure, or fall short of expectations.

In Russell (2008), it is recognised that growing student numbers (hence large lecture groups) are eroding the potential for teachers and learners to communicate in "a meaningful way", thus describing how formative assessment and teaching can be integrated using EVS. Russell's motivation is to enhance teaching and learning for large groups. This work is reviewed as it shares common ground with own research. EVS is used, as in the case of this research, to make purposeful adaptations. (Russell, 2008) also looks at how questions can be coupled around themes. The paper is written with reference to a cohort of technology students on an engineering science module. The undergraduate course is a BSc, not BEng and as such students have historically struggled, according to Russell, to get to grips with the mechanical principles covered as part of the module. This is due to the lower entry requirement in mathematics. Russell has attempted to improve teaching and learning through the use of EVS. There are parallels between this research and that of Russell's (2008) and there is merit in Russell's work worthy of consideration. The value of good lectures cannot be overstated and what defines a good lecture is one that is both engaging and stimulating to the extent that it inspires learners to seek further knowledge. A good lecture should seek to go beyond this by drawing together various components of the curriculum, establishing a suitable learning environment and integrating assessment tasks all of which promote positive encouragement for learning. This has been previously discussed and has been referred to as Aligned Teaching, (also called constructively aligned teaching) (Biggs, 2003). Purposeful integration of assessment and integrating disparate parts of the curriculum are also an essential aspect of ICEE (Integrated Concurrent Engineering Education- a teaching concept I aim to introduce as part of the research, specifically for engineering education) and encourages learners to think about a topic area on a macro as well as micro level. A major obstruction of large class teaching is that it makes dialogic activity more difficult, hence the reason why this is often more of a didactic nature, which is educationally less robust. A dialogic activity implies that a learning-conversation needs to be constructed between learners and the teacher (Laurillard, 2002) to the point that a meaningful conversation should allow for meaningful teaching adaptations based on what is emanated by the behaviour of learners with regard to their conceptions and misconceptions of the subject. EVS helps to implement a dialogic approach to teaching and learning as well as integrating assessment and learning, in a formative way. All the benefits reported by

Russell, (2008) are in compliance with earlier reviewed work such as prompt feedback being a feature of good practice. As is often the concern with EVS, students tend to guess in multiple-choice if they are unsure or simply don't know the answer. The response score denoting the proportion of learners who have grasped a concept may therefore not denote an accurate representation. Russell, (2008), suggests that presenting the same question in different ways resolves this issue. However, it is also suggested that, based on exploration, there should an optimal number of questions per session and this is suggested at eight. Ultimately, there has to be reason for adopting the technology and not just because it exists. The cited work on EVS systems report positively on its use as an integrated part of delivery, providing formative feedback, but does not quantify improvement in learning through assessment.

Zhang, (2003), provides a comprehensive overview of e-learning and enabling technology. He makes some valid and substantiated observations and concludes his paper by identifying areas that he suggests require future research directions. Of his key observation is that learning is rapidly shifting from instructor-centred to learner-centred, allowing for a more flexible way of learning; also referred as a shift from instructor-centric and learner-centric learning. This shift can provide key pedagogical benefits, in that it can emphasise relevance and personalization to the learner (in accordance to their own interest, prior knowledge and learning pace and style etc.). The gradual transition from teacher to facilitator as a result of e-learning interventions is also supported in the publications of Salmon, (2008) indicating that this growing trend continues. Although e-learning can be defined in several ways, Zhang's definition is simple and clear in that it refers to any type of learning situation when the instructional content is delivered electronically via the Internet when and where people need it. It does not specify the extent of content requiring electronic access, therefore blended delivery that utilises the internet for either synchronous or asynchronous access, however small, can still be classed as e-learning. Despite the great flexibility offered by asynchronous access to learning, synchronous learning cannot be overlooked as it often remains situated within grounded theories that enable individuals to feel more as if they are members of a learning group, more so than asynchronous access to learning, can do. Within the academic community, e-learning has supported significant improvements in interactivity, collaboration and delivery of education, fully or partially online. Zhang lists the many benefits of e-learning, including self-paced and just-for-me. E-learning can encourage learners to ask questions that they wouldn't otherwise ask within a whole classroom environment due to inhibition. The same applies when it comes to eliciting personal opinions, share ideas with each other (which they are able to do in smaller groups online, through forums). The same holds true when it comes to responding to questions within a classroom environment through the use of EVSs which proves that e-learning and formative feedback can be delivered in a traditional classroom setting with the result of engaging learners without inhibiting them. Zhang also reports on the negative effects of e-learning where three class formats are compared: traditional, web-based and hybrid. A study by (Rivera and McAlister, (2001) showed no significant difference in exam scores between the three. Students enrolled in the web-based delivery were in fact, less satisfied. This research and the cases considered lean towards a hybrid model of delivery. Other forms of e-learning include multimedia and audio-visual (streaming). The benefits of YouTube streaming were covered in an earlier review based on Clifton and Mann, (2011). Multimedia combined with audio-visual streaming (and podcasting) are claimed to have a dramatic impact on the process and product of learning due to multi-sensory learning environments which can help the learner's ability to retain information (Syed, 2001) . This has also been shown earlier (Weston and Barker, 2001), that such multimedia instructions can enhance problem solving skills and entice learners to longer and fuller attention (actively, intriguing or fascinating). Audio visual is claimed (Hampapur and Jain, 1998) to be by far one of the most powerful and expressive non-textual forms of to present information, potentially. Students also find video-based learning environments very absorbing (William et al., 1992).

Zhang, (2003) claims that the incorporation of communication and collaboration tools can enhance e-learning effectiveness. VLEs used as a tool for e-learning must be populated with sufficient information, as some for example, may only be no more than repositories for PowerPoint lecture slides. This is an issue identified by Zhang and therefore does not promote pedagogical improvements in terms of allowing the users to grasp a better understanding of the content. In the researcher's opinion, what is therefore required is more synchronized release of content such as more detailed explanatory notes that embellish the class content, link sites for further information and reading, video clips and possibly podcasts. Interaction is limited though this is said to improve as VLEs become better developed and grow over time with many possibilities such as assessing learners' performance and make dynamic adjustments to instructional content accordingly.

What is evident as common amongst the reviewed work in e-learning is that whilst learning trends amongst younger learners has changed considerably, a consistently coherent model of delivery is difficult to achieve for facilitators. The temptation is for a technology-led solution but the evidence points to the shortcomings in such an approach, it is not a 'panacea' for the internet generation (Skiba, 2007).

2.8 Review of teaching and learning strategies articles

Laurillard (2002) identifies four aspects to a dialogic teaching and learning session in which meaningful adaptations are made. He suggests that different educational media can be analysed and used in order to satisfy these dimensions. The framework which is illustrated in figure 2.8 is a practical framework for designing educational environments. Such a framework is very relevant to higher education, more so than any other educational sector, because it is geared to assist learners in seeing the world of work as it really is. As such, the associated pedagogic strategy should consider the media of communication and activities including discussion, adaptation, interaction and reflection.

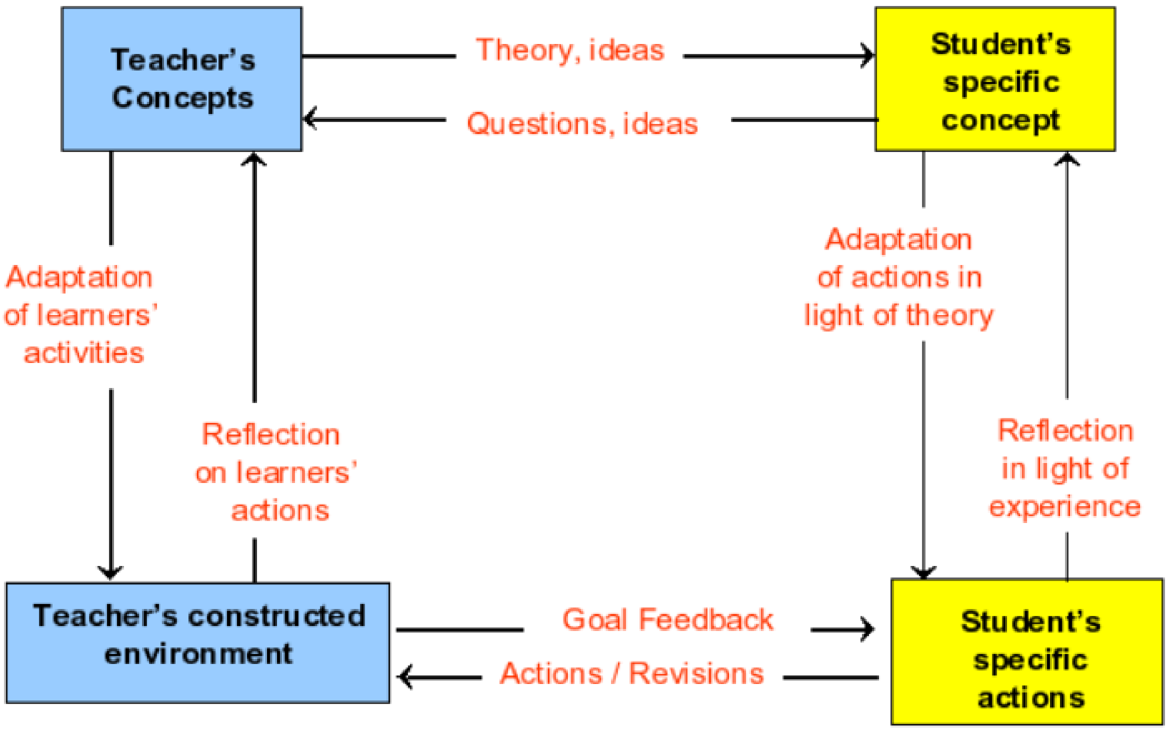


Figure 2.8: Laurillard's Conversational Framework. Reproduced from (Laurillard, 2002).

Complimenting Laurillard's Conversational Framework is Kolb's experiential learning theory (McLeod, 2017), as applied by Martin, (2015). Kolb's experiential learning style theory works on what is known as a four-stage cycle of learning and four separate learning styles. He professed that knowledge was acquired through abstract concepts which could be applied in a range of situations. As Kolb (1984) put it:

> "Learning is the process whereby knowledge is created through the transformation of experience".

Kolb's four-stage cycle of learning is evident in the instruction process of part-time undergraduate students, who are sponsored by an employer. Owing to having day to day practical 'real-life' day to day engineering practice experiences, they are more readily able to relate to their experiences and though piecing together class based information and existing experiences are more readily able to form new concepts and demonstrate hypothesis in new challenges. An example of where this is evident is in the subject of engineering design. The four stage experiential learning cycle is illustrated in figure 2.9.

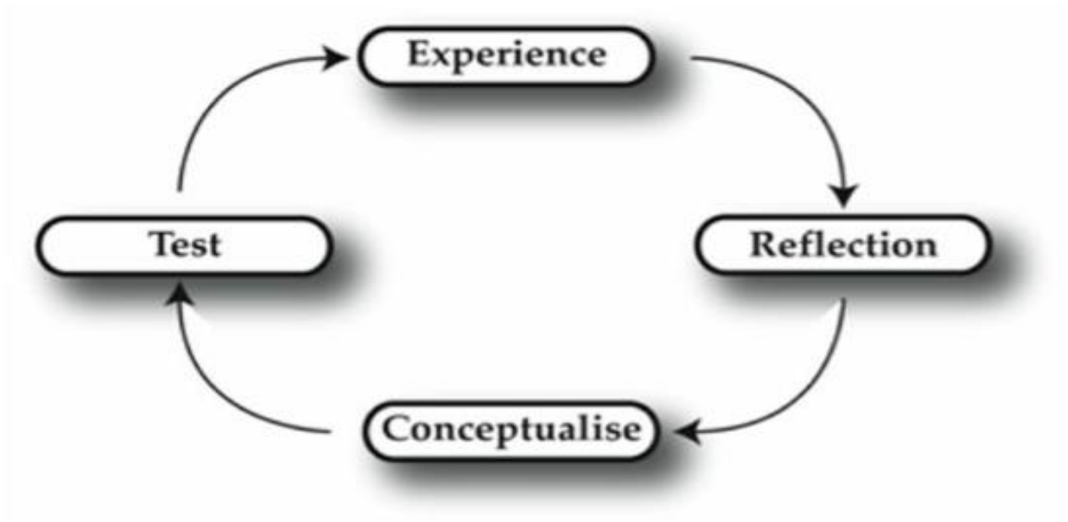


Figure 2.9: Kolb's four stage learning cycle. An integrated process in which each stage is mutually supportive, feeding into the next. It is possible for the learner to enter the cycle at any stage and follow the logical sequence. Reproduced from (McLeod, 2017).

Leaning is most effective when all four stages are executed. According to McLeod, (2017), Kolb's learning cycle can be used by teachers to critically evaluate learning provision made available to students but also to develop more learning opportunities. Guskey, (2010) comprehensively reviewed the historical sequence of research from Bloom's taxonomy to the development of mastery learning. He identified similarities to one-to-one tutoring process in which formative assessment follows delivery then followed by enrichment activity (or activities) for corrections followed by more formative assessment. The extensive research that has been undertaken on such instructional strategies are claimed by Guskey, (2010), to result in an improvement in achievement as shown in figure 2.10.

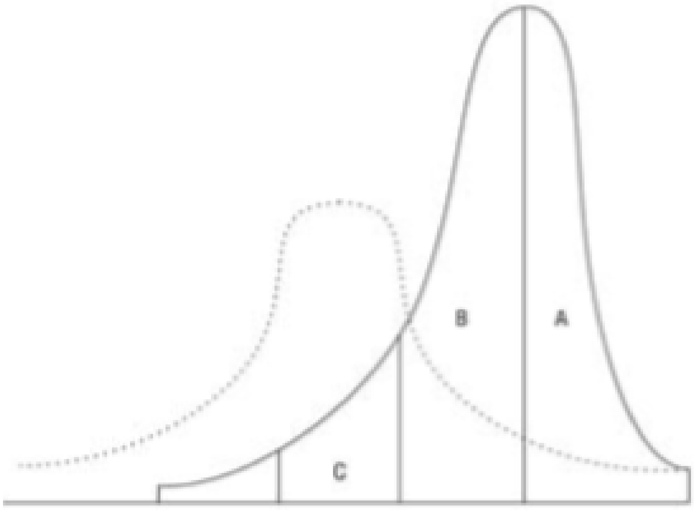


Figure 2.10: Distribution of achievement though mastery learning classrooms, in accordance with effective teaching and learning strategies. Letters indicate the grades and their distribution. Dotted boundary indicates distribution of achievement in traditional class. Reproduced from (Guskey, 2010).

Hopfenbeck, (2018), provides an editorial review article of the work of Black and Wiliam, (1998), twenty years following its publication. Black and Wiliam's main contribution to our understanding of teaching, learning, and assessment is assessment for learning and the role of the relationship between feedback, self-assessment and formative assessment. Hopfenbeck, (2018), states that for research in assessment to move forward teaching and learning forward must pay greater attention to understanding students' backgrounds, in terms of social standing and lives across cultures and contexts. There is a claim by Hopfenbeck, (2018) that there is too much debate on the theoretical definition of assessment for learning and formative assessment (as well as summative) without much of it translating into teachers' practices. This is because it is far more challenging for teachers to understand these differences while teaching and hence they unable to "implement formative assessment practices in their instruction" (Black and Wiliam, 2018, p.545).
Formative assessment lacks a strong research base, according to (Anderson and Palm, 2018). This can be contested should the researcher considers the work of Black and Wiliam (2018). Schneider and Randel, (2010), eight years prior, also claimed the same as Anderson and Palm, (2018), especially for professional development programmes in formative assessment and their impact on teacher practice and student achievement. One of the major challenges lies in the variance

between learner abilities, interruption and time pressure. The challenges that continue to exist for teachers and the gap in research are testimony to the need for closing the gap between theoretical and practical frameworks. There is therefore a clear need for empirical studies to move the knowledge of formative assessment forward.

In a separate book review by Wiliam, (2018), the following summarising statement is given by Hopfenbeck:

> *"Wiliam claims that given the present strength of the evidence for the effectiveness of formative assessment, or assessment for learning, it is somehow surprising that the implementation of better classroom practises has not been more evident."*

In an editorial review by Wiliam, (2017) on, 'Learning and Assessment: a long winding road?' commences by citing Baird et al., (2017) and stating that, historically, learning and assessment, have been "fields apart". Many authors have viewed assessment and learning as separate for different reasons. One view was they are unrelated processes because one entailed filling the learners mind with information whilst the other involves taking stock. William, (2017), affirms that the relationship between learning and assessment is far more complex than that which is magnified in complexity when considered in a social context (assessed group activity). The work of Baird et al., (2017) has posed a great challenge to address what is an extremely difficult task in resolving the key issues in order to suggest how they may be progressed forward. A key question that emerges from Baird et al., is whether attempts at quantifying are useful and predictive. Using theories of assessment to improve learning there is a danger in making an assumption that the stages through which a learner progresses are related to how well that learner performs having completed the sequence of learning, states Wiliam (2017). Yet that may not necessarily be true. What Wiliam (2017) asserts is that by incorporating a sequence of formative assessment for learning does not necessarily result in better performance in a final formal summative assessment. An example of this is when EVS is introduced as an intervention to gauge overall class understanding of a subject. The two key areas identified as being key to assessment and learning are technology and the social and emotional aspects of learning (i.e. group work). The researcher proposes to incorporate this as part of interventions within the first case study. The research question here is whether this, along with more traditional practice of experiential learning and reflection, enhance learning. Wiliam (2007) merely speculates (despite his assertiveness) that incorporating formative assessment for learning does not necessarily result in improved summative assessment. It is not based quantitative study.

Wiliam (2018) identifies that despite the idea that formative assessment can improve learning, education as well as a measure of its effects, globally, its systematic use to improve learning (formative assessment) appears to have gained little popularity and remains the exception rather than the rule. There is a weight of evidence behind formative assessment practice to improve teaching and learning but a good reason for examples in failure of improvements is attributed to the lack of consistent implementation. Since Black and Wiliam's (1998) large scale study, evidence has grown strongly to support the practice of formative assessment for learning, as it can have a substantial impact on student learning. Studies have found that certain key components of formative assessment such as feedback, self-directed learning and cooperative learning are, individually, very cost-effective (Education Endowment Foundation, 2015). Despite the evidence, some authors have questioned whether formative assessment does in fact have a large impact on student achievement (Higgins, 2014, Kingston and Nash, 2015,). Improvement in assessment after interventions are often quoted in effect size and whilst Hattie and Timperley, (2007) have quoted ranges of improvement in the range of 0.4-0.7, to the contrary, (Kingston and Nash, 2015) found an average effect size of 0.2 improvement. What is unclear are the ages and educational level of sample groups, so the research evidence does not appear to be as clear-cut as I may wish it to be. Hattie's primary research was conducted in schools therefore does not carry much weight when considered for more mature young adult learners. However, from what has been reviewed, thus far, there is sufficient evidence which points towards formative assessment or assessment for learning playing an important role in educational achievement. What perhaps remains a grey area is how we define assessment for learning and how we define or identify educational achievement. As an example given by Wiliam, (2018), a process that informs a teacher that a sequence of activities has not been successful, but provides guidance for improvement in delivering teaching, may not, according to some definitions, be regarded as assessment for learning. This implies that even when a teacher is following a process of delivery and discussion, formative assessment for learning may be absent. Wiliam, (2017), provides a commentary of Baird et al., (2017) which acknowledges that establishing a link between theories of learning and theories of assessment is difficult. Reflection and discussion are a form of formative assessment for learning. It is partly on this basis that I formulated the case studies. Assessment for learning can consist of posing questions based on delivery in order to assess the level understanding or learning.

Ziming (2008) examines and compares the structure of two undergraduate engineering programmes at two different universities in order to align the learning outcomes. Whilst one of them is of three years' duration, the other is of four years duration. Compatibility was sought in order that the standard attained was the same for both courses, so whilst they were of different duration, alignment could be achieved between the two programmes. From a teaching and learning perspective, the Ziming sought to avoid conventional serial delivery of traditional subjects such as mathematics, engineering science and materials technology, but sought to introduce a more laboratory and project type delivery which would integrate delivery of several topics within individual projects. The problem with conventional delivery is that it lacks integration between theory and practice thus falling short of industry skills requirements, claims Ziming, (2008), who has introduced what they call an "Industry-Oriented Teaching and Learning" pedagogy into the traditional engineering degree. Ziming compares exam results between two sets of students, one of which has followed the revised format whilst the other has not and reports on significant improvements in final exam results. The exam was laboratory based and combined a practical and written format. It was of 5 hours' duration.

How much of the knowledge gained by students is procedural and how much of it is conceptual? This is the question posed by Daud et al., (2012), with reference to 3D Computer Aided Design (3D CAD). 3D CAD is covered throughout undergraduate mechanical engineering programmes. Even though the early stages of delivery focus on its fundamental use as a technical graphics communication application, the authors' objective was to determine whether learners could differentiate between procedural and conceptual use. The emphasis was on procedural knowledge in that students could not identify with the wider context of 3D CAD as an engineer's tool, and the array of applications (such as product manipulation, surface design, product data transfer for sharing etc.). A Concept Map to assess students' conceptual understanding on 3D modelling techniques had established this. The study reveals a shortfall in effective delivery and identifying the need for improved delivery techniques. Although the study was limited in terms of the number of students (less than fifty) it was applied to, it revealed the procedural manner in which students learn 3D CAD.

Gupta, (2008), addresses the subject of problem solving with reference to engineering education and recommends numerous methods by which to approach and resolve engineering problems in the classroom. He strongly advises that educators should primarily focus on teaching problem solving methods as opposed to focusing solely on the solutions to particular problems (i.e. "Here is the problem and here is the solution to the problem"). This only results in learners expecting identical problems for which they can follow (through recall) the identical procedure to resolve it. By incorporating multiple methods of problem solving within the classroom and deliberately focusing explicitly solely on solutions to particular problems, then learners will become better problem solvers. Such learning is especially applicable to engineering, which, as Gupta puts it "is a profession of problem solving, and to engineering education, which relies heavily on problem solving as a vehicle for learning". Problem solving skills is of particular importance and universally recognised, however, teaching such skills remains a challenge in engineering education. There has been a long search for ways to improve such skills in engineering education. Awareness of various problem-solving methods forms an important part of learners' metacognitive knowledge which can be greatly enhanced through demonstration and discussion of the methods. Gupta covers ten problem solving methods commonly used with elementary engineering problems. The article also emphasises the importance of teaching such problem solving methods in the context of the subject matter rather than in the abstract (and a variety of them) because different learners conceptualise and approach problems differently. A variety of methods will help to reach learners with diverse abilities.

Freeman et al., (2014), carried out an extensive meta-analysis of 225 studies (extensively sourced based on worldwide publications on active learning) in order to ascertain whether active learning improves student performance as compared to traditional lecturing. The research was applied to only STEM subjects and the research questions were (i) Does active learning boost examination scores? And (ii) Does it lower failure rates? A general consensus definition is first required for both active and tradition learning and the authors defined these as,

> *"Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work."*

And traditional lecturing is defined as,

> *"…continuous exposition by the teacher." Under this definition, student activity was assumed to be limited to taking notes and/or asking occasional and unprompted questions of the instructor.*

The results of the meta-analysis of the research by Freeman et al., (2014), indicated that the average improvement in examination scores had improved by approximately 6% in active learning. The research also indicated that students with traditional lecturing were 1.5 times more likely to fail than students who in classes with active learning. This is equivalent to failure rates of 21.8% under active learning as compared to 33.8% under traditional learning (an increase of 55%), according to Freeman et al., (2014). The results are reported to hold true across the STEM disciplines irrespective of class sizes, although the greatest effects are in class sizes of less than 50 learners and at increasing performance on concept inventories (*NB A concept inventory is a criterion-referenced test designed to help determine whether a student has an accurate working knowledge of a specific set of concepts*). The authors of this report claim that their analysis is the largest and most comprehensive meta-analysis (of 225 studies in published and unpublished literature) of undergraduate STEM education published to date. Their study is robust and considers variation in methodical rigor as to what is included in the range of studies, based on the quality of controls over student quality and instructor identity. On the evidence of the research by Freeman et al., (2014), the embracing of active learning, universally, could help reduce the problem of high dropout rates in STEM subjects (only 40% of students who enter university with an interest in STEM, in the USA actually finish with a STEM degree).

Streveler and Muhsin, (2017), provide an editorial review in which they scrutinise Active Learning as a universal solution for improving all teaching and learning. Common research design practice applies a pairwise method for comparison in which one pedagogical method compared with another method and the results are analysed to judge which seems to be the more effective. The standard benchmark as a comparison is commonly the traditional lecture versus active learning, which may include one (or more) of many pedagogical frameworks encompassing a wide spectrum of activities – such as Project Based Learning, Games Based learning, Problem Based Learning, Collaborative Learning, for example. The question as to whether active learning works has been subject to question by several researchers in engineering educational research, for instance, Streveler and Smith, (2006), and the general consensus is that it does for most types of students (Freeman et al.,, 2014). This view was also supported earlier by Prince, (2004), who conducted an extensive literature review confirming a positive trend. This, however, was not quantified. The reality of this, as argued by Streveler and Muhsin, (2017), requires more refinement as it is nuanced therefore loses conviction . To do this, Streveler and Muhsin, (2017), make an analogy to the following question:

"Is it better to be physically active rather than sedentary?"

The answer may appear to be obvious if you grouped people who were active and compared them to inactive people, yet there are less obvious, yet important questions to raise such as:

- The kind of exercise/activity (degree of vigour)
- One activity type compared to another
- The optimum amount of activity
- The individuals subjected to that activity (ability and disability and age factors).

Thus, they assert that when we refer to active learning we must consider:

- The learning activities
- The subject discipline
- The subjects and topics being taught
- The associated learning objectives, and
- The learner/students doing the learning.

Streveler and Muhsin, (2017), cite two frameworks in order to help classify active learning activities. The first is referenced to Chi, (2009), who developed the ***interactive-constructive-active-passive*** (ICAP) framework that categorises behaviours and compares them to resulting learning outcomes. Several examples are given in Streveler and Muhsin, (2017), including ones when learning is further enhanced though collaboration or cooperative learning.

The effectiveness of interactive activities also depends on the domain or topic studied, as well as the profile of the learner, report Streveler and Muhsin, (2017).

The second cited framework is the ***knowledge integration framework,*** which is used to design learning activities to teach complex concepts through scaffolded knowledge, which dynamically links, organises and differentiates patterns, ideas and theories in order to rationalise a specific concept. It may be based on previous basis concepts and observations from everyday life. The framework was proposed by Linn, (2000), who defined the knowledge integration environment (KIE) principles and guidelines for designing learning activities to promote integrated understanding of complex concepts. According to the KIE principles, an effective design of integrated learning activity should:

- ***Make content accessible*** through encouragement to explore and investigate personally-relevant problems in order to connect new and existing knowledge
- ***Make thinking visible*** by embedding and providing multiple visual representations to model the scientific phenomena
- ***Help students learn from each other*** by incorporating multiple social activity structures to promote collaborative interactions, and
- ***Promote lifelong learning*** by establishing a general process of inquisitiveness and inquiry suitable for diverse learning projects.

Streveler and Muhsin, (2017) concluded that active learning is not a panacea to remedy all in instructional inadequacies. It represents a group of instructional strategies that can produce different results on the basis of the requirement of differing degrees of time to design, plan, implement and assess. By being more specific about descriptions of active learning the researcher is more able to ask particular research questions. In this way, he is able to design the instructional strategies most suited to the learners being taught. When creating interventions, frameworks like KIE may be used as a guide, recommend the authors. So the key question asked by Streveler and Muhsin, (2017) is:

"What kind of active method produces the highest learning in specific settings, or with specific kinds of students?"

The researcher identified the profile of learners and the documented evidence points favourably towards active learning. However, in having considered the work of Streveler and Muhsin, I can address the research question as to what works best with the cohort of students subject to this research, in general terms, and to what extent. For what reasons does active learning fail to make quantifiable improvements with certain learners?

2.9 Collaborative learning

In Gillies et al., (2008), the factors that mediate and moderate learning within small groups are examined. Certain conditions for successful peer to peer learning to occur, have to be met and these are also examined. What becomes clear in Gillies et al., (2008), is that many teachers encounter difficulties in successfully implementing the pedagogical practice of cooperative learning within class. This was also previously reported by Cohen, (1994). This is despite the well documented benefits of cooperative learning practice. This may be partly due to lack of understanding as to how to establish cooperative groups and how to translate research and theoretical perspectives into practical applications, according to Cohen. According to Gillies et al., (2008), the key to establishing cooperative learning is through commitment to embedding the procedures into the curriculum, implementing it and then monitoring it and evaluating it.

Mann, (2005), considers issues which act as barriers to learning within collaborative learning 'communities'. By this the author refers to classroom and online learning communities. A number of examples are given. 'Failure of communication' is suggested as the main need to focus on in order to establish successful online learning environments that are most likely to support engaged collaborative learning. Learners often feel estranged and alienated from the subject and the process within groups, hence the learning process is hindered. They may therefore feel unable to engage and contribute in ways which are productive and meaningful due to realisations of their own potential and learning requirements. This may sometimes be simply due to language barriers especially in mixed cultural and nationality groups. Feelings of isolation from what they are supposed to be learning may result. This alienation of learners in face-to-face higher education contexts has also been reported by Read et al., (2003). One of the examples given by Mann, (2005), with reference to a classroom environment is the view of a learner who states that: *'Everybody wants to know but nobody wants to ask a question'.* This results in learners feeling constrained form engaging actively. This may also be due to preconceptions of what is supposed to be a 'good' learner – one who is independent and clever (suggests Mann, 2005). In another example, learners and the teacher feel alienated from each other through lack of knowledge about different experiences each has in a face-to-face classroom environment (there is therefore lack of clarity in what is expected from each other in terms of behaviour and engagement). This can be an issue when confronted with classes that are made up of multicultural groups of learners from a wide range of international educational systems. It has been previously been suggested that with the use of asynchronous learning environments (e-learning) acts as a means to minimise some of the alienating constraints posed by conventional face-to-face learning environments but other research suggests that this may not always hold true (Conrad, 2002, Sujo de Montes et al., 2002). Online learning communities only work if there are strong relationships between learners. Garrison and Anderson, (2003), describe this as a requirement of fusion between 'cognitive independence' and 'social interdependence'. Without the strong social interdependence, online learning environments increase the problem of establishing an identity of the learning group, the norms and how individuals fit into the group. Mann, (2005), argues that the opportunity for communication is key to effective collaborative learning and may be addressed with opening up opportunities for expression, seeking understanding, making explicit norms and assumptions in order to question them and configure them appropriately, getting to know the learners, familiarisation with different experiences and needs, voicing different experiences and more. There is therefore a need to facilitate dialogue in the learning group, rather than just seeking to establish as sense of belonging to a learning community. This applies to both asynchronous e-learning as well as collaborative class based learning.

2.10 The flipped learning (or flipped classroom) approach to teaching and learning

This section reviews previous work in the flipped classroom approach to teaching and learning in order to compare practices and further assist in the formulation of the research practice, as well as identifying gaps. In the flipped classroom approach students are given work prior to timetabled lecture or other teaching and learning session. It relies on students carrying out independent study. It therefore relies on the motivation and willingness of the learner to undertake such study. A common worry is that students may be either “incapable of, and unwilling to, work alone” (Gibbs 1981). Prior study and arriving prepared is not a new idea but with the advent of technology and e-learning this has been rejuvenated whilst also make it possible for scaling up to large classroom situations.

Martin, (2015) attempted to integrate alternative teaching and learning methods in order to enhance the traditional PowerPoint lecture. The subject area was applied science, which bears some similarities to engineering and technology. The subject of manufacturing technology requires a more visual approach coupled with discussion in order to address more detailed aspects, in my opinion. Martin, (2015) takes a flipped classroom approach to deliver a specific topic which forms part of a microbiology module, specifically, how bacteria grow and how they are counted. The topic requires some application of mathematical formulas so that learners who historically struggle to get to grips with the topic are assisted. Generally, many of the students appeared to disappear in the background as the group sizes were in excess of 100. The main obstacle to this was being able to pitch the lecture at the right level due to variations in levels of maths by the learners. It was therefore difficult to be inspiring as some learners were lost. Martin’s revised approach was a blended one that entailed a mixture of techniques including:

1. A screencast prior to formal didactic delivery, which covered the lecture content in brief (or the essence of the lecture)
2. Feedback questions based on the screencast using EVS and voting pads/clickers.
3. Didactic session to guide learners on the calculation procedure
4. A short animation using Video-scribe animation software
5. Short break
6. A game based on the content.

A separate session would introduce tutorial questions for further reinforcement of the topic. Martin had broken the session down into smaller activities of no more than 15-20 minutes – It applies Bigg's (2003) principle that there should be changes in the sessions at between 15-20 minutes. This is because, according to Biggs, the typical attention span of students in a lecture-style environment is usually no more than 15 minutes, therefore he advocates change or rest after this time.

Martin also drew from Kolb's (1994) theory on Experiential Learning as well as Ramsdens's six key principles of effective teaching (Ramsden, 1992) as listed below.

> *"1. Making a teaching session interesting and giving clear expectations*
> *2. Showing concern and respect for students and student learning*
> *3. Giving appropriate assessment and feedback*
> *4. Providing clear goals and intellectual challenge*
> *5. Ensuring independence, control and active engagement of learners*
> *6. Learning from students"*

Pedagogically, Martin's, (2015) revised session worked well with positive feedback from learners, however, a key problem was identified that the researcher can draw lessons from. Trying out new strategies does not go without risk, especially when it entails unfamiliar and not fully tested technology. It relied on activities that were based on technology (Videoscribe animation, EVS and screencast) and problems were apparent and reported. Another problem reported was that due to the attempt to incorporate so many technology-based activities, delivery of the topic took longer than anticipated.

In Bates and Galloway, (2012), the authors present a practice-based revised approach for delivering to a large cohort (of approximately 200) on a year 1 undergraduate physics course, at the University of Edinburgh. They describe how they have moved away from traditional delivery to an inverted class approach (flipped classroom) and have used clickers (voting pads as part of EVS) in order to evaluate what learners had actually retained as part of their upfront learning. Materials provided prior to timetable sessions included textbook reading and reference websites. Session would then become more like guided discussion sessions with the use of an EVS. Once there was clarification of the areas of learner difficulties (as indicated by the learners through an online VLE quiz) the facilitator would tailor the session accordingly with discussion. This is reported by the authors to have worked well, despite early concerns, resulting in improved end of year performance in the subject examination. The same amount of material (curriculum) was covered as prior to the change of delivery. An early concern was one of increased staff workload and the requirement for much increase in upfront preparation. Sourcing websites, preparing quizzes, EVS discussion questions all demanded extra staff time. The traditional lecture is a highly efficient means of delivery. Some of the tasks such as analysis of quizzes to establish what exactly learners were unclear about or had difficulties with were analysed by graduate teaching assistants. Other concerns related to exactly how much time were students prepared to dedicate prior to class. This is said to have been an unfounded concern. However, Bates and Galloway do present a strong case for the flipped classroom.

In each of the two cases considered (Martin, 2015, Bates and Galloway, 2012) make reference to work of Biggs, (2003) for alternative learning strategies. In the first, Martin, (2015) applies the principle of frequent (every 15-20 mins) activity change and Bates and Galloway, (2012) apply Bigg's 'constructive alignment' (Biggs, 2003). In fact, it is evident from the literature that 'constructive alignment' is applied in Martin, and Bates & Galloway. 'Constructive alignment' first assumes that the learner constructs their own learning through a relevant learning activity, for example, lecture, AV, online quizzes, reference website. The teacher creates the appropriate learning activities in order to achieve the relevant learning outcomes. All components require the support of the teaching system. The teaching system includes the facilities, curriculum and intended outcomes, applied methods and assessment tasks. The activities and the outcomes must align with each other, hence the term 'constructive alignment'. According to Biggs, (2003), teaching and learning for 'constructive alignment' must be part of a whole system that embraces classroom activity and environment as well as department and institutional support. If the whole system is not integrated and in-tune, then high-level learning is not supported and does not take place.

The 'alignment' aspect refers to what the facilitator does in order to align, or support the activities for learners to achieve the learning outcomes. Therefore, teaching methods and assessment tasks should be aligned so that the intended outcomes are met. Outcomes are defined by the level of understanding students are required to achieve them. There are four major steps to achieving this:

1. Defining the intended learning outcomes (ILOs)
2. Choosing teaching/learning activities likely to lead to the ILOs
3. Assessing students' actual learning outcomes to see how well they match what was intended
4. Arriving at a final grade.

Biggs emphasises that ILOs must be specific, even down to the topic, about how well each topic needs to be understood. This gives opportunity for more able student to utilise declarative knowledge into functional knowledge. Functional knowledge better prepares graduates for professional careers as it enables them to apply knowledge for synthesising a solution. Functional knowledge can be thought of in terms of verbs (see Bloom's revised taxonomy), with examples such as hypothesise, solve unseen complex problems, and generate new alternatives.

A common problem that Biggs identifies is that too much of the teaching and learning in Higher Education remains within the low level verbs domain such as 'describe', 'identify', and 'memorise' in a system that aligns delivery with specific desired assessment outputs. "Intended Learning Outcomes (ILOs) cannot sensibly be stated in terms of marks obtained"; states Biggs (2003).

Bishop and Verleger, (2013), carried out a comprehensive review of the research published, to that date, on the Flipped Classroom (FC). It is sometimes referred as the inverted classroom, or Flipped Learning (FL). The principle has enjoyed rapid growth as a result of the technological movement in amplification and duplication of information at extremely low cost. This of course refers to the advent of the internet and AV recordings such as podcasts and YouTube. The term, FC, has now become very loosely used. Reference is made to MIT alumni Salman Khan who founded the Khan Academy in 2006 with the release of thousands of videos and practical online exercises. Khan's mission is to provide "a free world-class education to anyone anywhere" (2012). The key point being that is a vast pool of free online learning material. The authors therefore set out to define the term and associate it with educational frameworks. They define FC as a pedagogical method, which employs asynchronous video lectures, and practice problems as homework. Based on theoretical frameworks the authors insist that an important ingredient in FC is group-based problem solving within the classroom. Discussion questions where learners are required to collaborate, qualify as such. FC is claimed to represent a unique combination of learning theories that were once thought to be incompatible. These theories (active and problem-based) are founded on constructivist ideology as well as instructional lectures founded on behaviourist principles. Several messages are echoed in the paper that are in agreement with numerous other publications on the subject of FC; Reports on student perceptions are mixed but generally positive. The authors have identified that students prefer in-person delivered lectures to video lectures but also prefer interactive classroom activity. The evidence that FC provides for improved learning, is anecdotal, and the authors identify that there is very little by way of research based objective work that has investigated objectively, the learning outcomes as a result of FC.

> *"There is a limited amount of scholarly research on its effectiveness"*

They therefore identify a gap and a need for more controlled experimental or quasi-experimental work, particularly action research in this area and recommend that researchers also consider theoretical framework used to guide the design of in-class activities.

Reference is also made to the requirement for accredited courses which need to be endorsed by professional bodies such as the Accreditation Board for Engineering and Technology (ABET), which is US-based, and the Institution of Engineering and Technology (IET), which is the UK-based equivalent. Accreditation of courses defines learning outcome in terms of ability and knowledge such as,

> *"an ability to communicate effectively"*
>
> *"an ability to identify, formulate, and solve engineering problems"*
>
> *"ability to function on multidisciplinary teams"*

All of which are difficult to achieve through traditional informative lecture-based didactic teaching. Problem-based learning can be much more effective at achieving such goals with the only hindrance being that engineering courses are already generally packed and such an approach demands more time resource.

The ABET report defines the term flipped or inverted classroom (FC & IC) as consisting of two parts:

> *"Interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom"*

They also identify that FC is a term that is most often assigned to courses or subjects consisting of both asynchronous web-based AV lectures (or content) and in-class problems, quizzes and activities. All of which are to be considered and applied within this research framework.

2.11 Action research

Reason and Bradbury (2001) define action research as:

> *"…a participatory, democratic process concerned with developing practical knowledge in the pursuit of worthwhile human purposes . . . It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities"* (Reason & Bradbury, 2001 p. 1)

Another, and earlier, definition of Action Research by Kemmis and McTaggart, (1988), has been cited (Kemmis, 2010) as:

> "*Action research is a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational* ***practices****, as well as their* ***understanding*** *of these practices and the* ***situations*** *in which these practices are carried out." (Kemmis and McTaggart, (1988), 1; emphasis added)*

A more elaborative version is given later in this chapter.

The research questions outlined later in this chapter confirm that Action Research methodology is ideally suited in helping us address the research questions. It is for this reason that the researcher shall review some work on Action Research in this section.

Five principles for validating Educational Action Research (AR) are proposed (Heikkinen et al., 2012). These are detailed in table 2.3. The principles can be used to validate AR and can be employed as general guidelines for designing the whole research process. Heikkinen et al., emphasise that there are more than one way to validate AR. Kemmis advocates that all AR practices are founded through activities and actions.

Table 2.3: The five validation principles for action research (as reproduced and adapted from Heikkinen et al., 2012)

1. Principle of historical continuity *How has the action evolved historically?* *How logical and coherently does the narrative proceed?*
2. Principle of reflexivity *What's the nature of the researcher's relationship with his/her research?* *What are the researcher's presumptions of knowledge and reality?* *How does the researcher describe his/her material and methods?*
3. Principle of dialectics *How has the researcher's insight developed in dialogue with others?* *How does the report present different voices and interpretations?* *How genuine are the protagonists of the narrative?*
4. Principle of workability and ethics *How well does the research succeed in creating workable practices?* *What kind of discussion does the research provoke?* *How are ethical problems dealt with?* *Does the research make people believe in their own capabilities and possibilities to act and thereby encourage new practices and actions?*
5. Principle of evocativeness *How well does the research narrative evoke mental images, memories or emotions related to the theme?*

A pioneering researcher of Action Research is Stephen Kemmis who in 1986 asserted that AR aims to "change practices, people's understanding of their practices, and the conditions under which they practice". This was as AR was originally defined in Kemmis and McTaggart, (1986). A more elaborative version of action research appears in Kemmis and Taggart, (1988), as follows:

> ***"Action research is a form of collective, self-reflective inquiry that participants in social situations undertake to improve: (1) the rationality and justice of their own social or educational practices; (2) the participants' understanding of these practices and the situations in which they carry out these practices. Groups of participants can be teachers, students, parents, workplace***

> ***colleagues, social activists or any other community members – that is, any group with a shared concern and the motivation and will to address their shared concern. The approach is action research only when it is collaborative and achieved through the critically examined action of individual group members."***

In Kemmis, (2009), defined 'Action research as a practice-based practice'. Kemmis describes various types of AR and describes how the practices are changed through AR. This is achieved through understanding of own practice and the conditions under which the Action Researcher they practice (the practitioner's environment). Kemmis gives examples of AR in shaping practices in education, social work, nursing and medicine, where better practices should be helped through AR. The key phrase used with reference to AR being **"*practice-changing practice*"** as this is what it should always be, claims Kemmis.

Kemmis et al., (2014, p.38) state that our practices – teaching, learning, researching, for example – consist of what we say (the cognitive domain), what we do (the psychomotor domain), and how we relate to one another (the affective domain). These "sayings, doings, and relatings" are also called our actions.

By this he implies that transforming our practices involves firstly better understanding our practices, then changing our practices or actions. An example is given in transforming a type of educational practice (doing) – by changing to project based work which may entail a paradigm-shift from a conservative view of education to a more liberating self-formation shift in thinking and delivery (saying) as related to the subject (relating to learners). Parallels exist in fields where AR is applicable and as previously identified and practices can change practices in parallel fields, a term referred as meta-practice (Kemmis and Grootenboer, 2008).

Kemmis (2009) asserts that practitioners using action researcher should not be attempting to conform with existing theorists and theories, but for them to be a theorist and researcher with the intent of introducing intellectual and moral control over their own practice. It is through a self-reflecting process that they are remaking their own practice. It is a process of self-transformation.

As there are different kinds of AR, each involves different patterns of saying “saying, doing, relating”. Kemmis, McTaggart, and Nixon, (2005, 2014), have identified seven different types of AR:

1. Participatory research
2. Critical participatory action research
3. Classroom action research
4. Action learning
5. Action science
6. Soft systems approaches
7. Industrial action research.

They each differ in the kinds of issues and types of problems that they address as well as their settings and kinds of people involved. Of interest particular relevance to this study are two forms of action research: ***technical AR*** and ***practical AR***. According to Kemmis, (2009), in ***technical AR*** the aim of the participant-researcher is to improve the outcomes of their own practice. It can be a means to an ends in that in a classroom scenario it may lead to improved examination scores. The end is known, provided that the way in which others are involved in the practice changes (be it patients and how their medication is administered or students and how learning material is delivered). It is the practitioner who decides what is done and puts in place the interventions and what sense is made of the observations as a result of these. In technical AR there is a one-way relationship between the participant-researcher and the subjects involved and affected by the research. Technical AR is therefore guided by an interest in improving control over outcomes. In ***practical AR*** the research ‘project’ is also self-directed but with the difference in that those involved are also given a voice. The subjects therefore capable of speech and actions and as persons who will be effected by the consequences (this would be like the difference in AR practice between a teacher of nursery age children and that of adult learners who are encouraged to be expressive in changes of practice). The practitioner in cases of practical AR may still be the one who decides what is to be explored and the associated interventions but remains open to the views and responses of others and the consequences that result from the changes in experience as a result of the changes in practice. The others may not necessarily be the subjects of the research (as an example, it may be the guardians or parents of young adolescents).

In Altrichter et al., (2002), various definitions of AR are explored in an effort to avoid its confinement but rather offer it as a research methodology with wider participation. It presents several alternative approaches and argues for a sensible mix of pragmatic and flexible approaches for definition. The authors maintain that that AR must be clarified for communication and open for ongoing consideration. A broadly accepted approach to AR is better than a fixed definition as this would be consistent with the flexible, pragmatic, collective response to problem solving that action research advocates. Experiences must be shared or the action researcher must be prepared to “give away” their knowledge of AR, which is in the ethos of the collaborative research process of AR, uphold the authors and also in accordance to McTaggart, (1996).

Holly, (1996) argued that a purist definition of AR is disenfranchising or excluding. The example given is when a particular teacher introduces an AR project, it may be difficult for them to meet rigorous requirements of “participation” and “collaboration” from the outset. Insisting on rigour or dismissing the evolving research project as a “limited form of AR” only serves to discourage newcomers to the practice.

Two parts to AR are cited by Altrichter et al., (2002), the axiomatic part and the empirical part. In the axiomatic part indicates the meaning of AR whilst the empirical part presents an inventory of “rules of thumb” that collects reflected research experiences of action researchers. As an example given by Altrichter et al., (2002), at the start of a new course on AR, the first session, the axiomatic part is defined as follows:

1. AR is about people reflecting upon and improving their own practice
2. By tightly inter-linking their reflection and action and
3. Making their experiences public to other people concerned by and interested in the respective practice.

The empirical part which is the “inventory of rules” (and earlier referred to as “rules of thumb”, Altrichter et al., 2002) is potentially infinite. Some of the most fundamental features of AR such as participation and freedom and all its ethical considerations (such as democratic context and dissemination) are included in the empirical inventory of rules.

As a working definition of pragmatic AR, table 2.4 was compiled as part of an international symposium and reported by Altrichter et al., (2002).

Table 2.4: Working definition of action research, reproduced from (Altrichter et al., 2002)

If yours is a situation in which: • People reflect on and improve (or develop) their own work and their own situations • By tightly inter-linking their reflection and action: and • Also making their experience public not only to other participants but also to other persons interested and concerned about the work and the situation, i.e. their (public) theories and practices of the work and the situation; And yours is a situation in which there is increasingly: • Data-gathering by participants themselves (or with the help of others) in relation to their own questions; • Participation (in problem-posing and in answering questions) in decision-making • Power-sharing and the relative suspension of hierarchical ways of working towards industrial democracy; • Collaboration amongst members of the group as a “critical community”; • Self-reflection, self-evaluation and self-management by autonomous and responsible persons and groups; • Learning progressively (and publicly) by doing and by making mistakes in a “self-reflective spiral” of planning, acting, observing, reflecting, preplanning, etc.; • Reflection which supports the idea of the “(self-)reflective practitioner”; Then:

Yours is a situation in which action research is occurring.

According to Zuker-Skerritt, (2001), and as cited by Altrichter et al., (2002), another pragmatic form of defining and explaining AR is by means of spiral of cycles each consisting of four phases in AR, which are:

1. Planning
2. Acting
3. Observing and
4. Reflecting.

Kemmis et al., (2014b, p.18) describe AR in terms of 'a spiral of self-reflective cycles'.

This is diagrammatically illustrated in figure 2.11. It is a simple and helpful model of the continuous and iterative process, which entails research and development, intellectual inquiry and practical improvement, reflection and action.

Dick, (1991), describes AR a family of research methodologies which pursue simultaneous change through understanding by action and critical reflection and later by refinement of methods, data and interpretation through reiteration.

Zuber-Skerritt, (1992), generalise on the forms of AR that have evolved, by,

> *"Critical collaborative enquiry by reflective practitioners who are accountable in making the results of their enquiry public, self-evaluating in their practice, and engage in participative problem-solving and continuing professional development"*

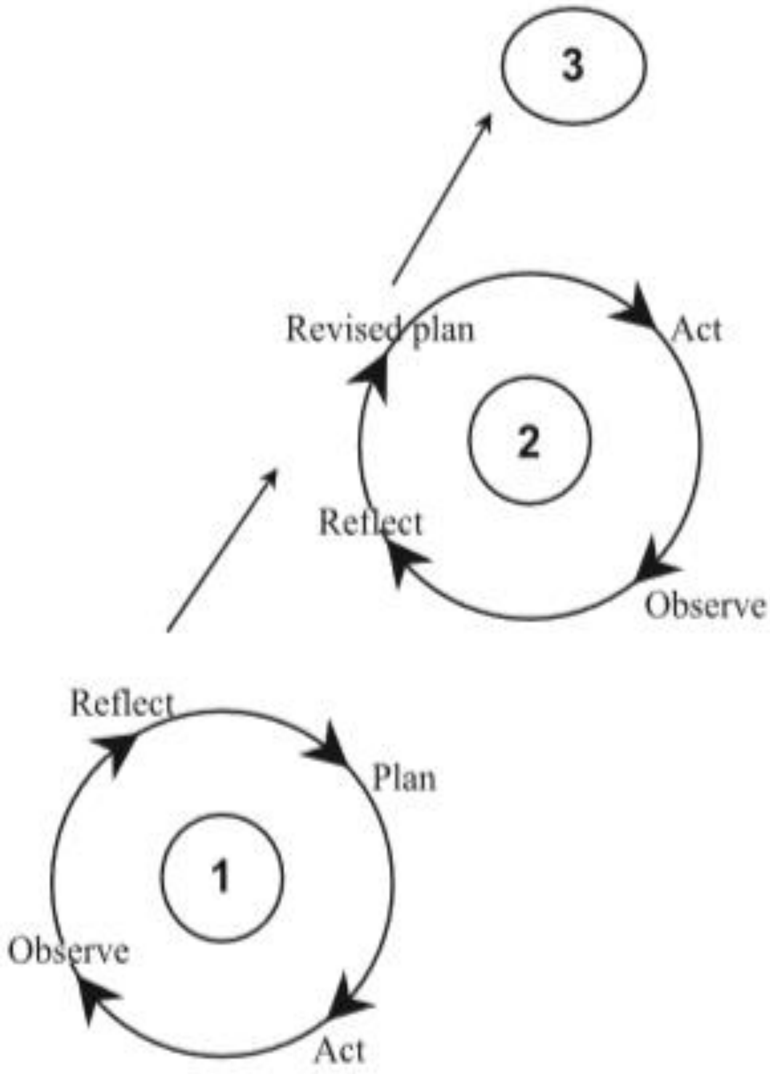


Figure 2.11: showing the spiral of action research. Reproduced from (Zuber-Skerritt, 2001, p.20)

Therefore, according to Zuber-Skerritt, (1992) view, AR is critical in the sense that practitioners look to improve their practice by being critical agents. It is a reflective practice in that participants analyse and develop concepts and theories based on their experiences. Acton researchers are also accountable in that they publish their findings.

According to the principle of historical continuity, good educational action research identifies the historical evolution of action that is required at both the macro and micro levels with continuity of historical action for both. As the instigation of action begins for a reason, the action does not end but evolves. Heikkinen et al., (2012), states that the researcher should have sufficiently studied the historical background to the topic. They also identify what is referred to as the “the principle of reflexivity” which means that a good researcher has instinctive awareness of his/her way of knowing. This is based on reflective thinking which is pivotal for the action researcher and also closely related to the epistemological analysis (analysis of the presumptions concerning knowledge). Figure 2.12 illustrates this. Presumptions or propositions are made based on the epistemological analysis. The principle of reflexivity also stresses that the research should be transparent in that material and methods should be well defined in a research report. It is based on the assumption that researchers often fail to sufficiently display their interpretive work. They may fail to show their human influence in the process of selecting, interpreting, analysing and reporting data. Such situations raise issues of credibility which can encompass political and ethical issues. Developing of further research action is based on reflection of previous action. It also assists as momentum to trigger the next step of action. Heikkinen et al., (2012) also discuss the importance of dialectics to AR, which is the process of interpersonal discussion in order to accommodate different opinions and interpretations. They also comment on that what they consider as constituting good AR with reference to evocativeness. By this, they imply that good research “awakens and provokes thought about things in a new and different way” and that “the most significant learning experiences are always both cognitive and affective in nature”.

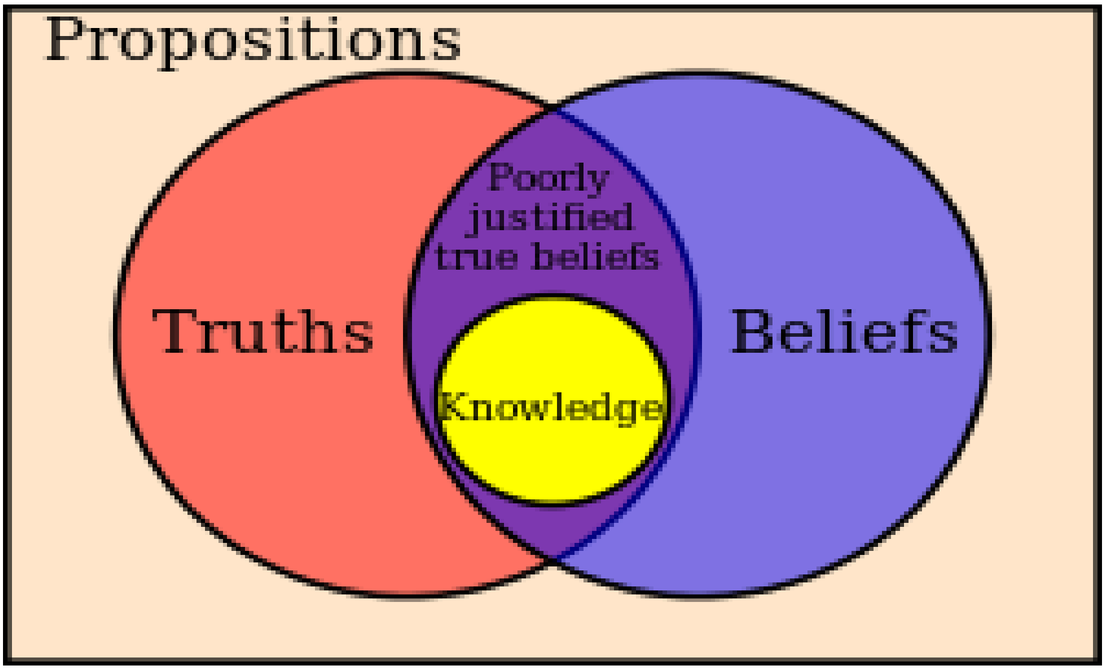


Figure 2.12: Reflective thinking in Action Research leads to knowledge based on truths from research data and beliefs. This is epistemology, which is derived from the Greek words 'episteme' meaning knowledge, and 'logos' meaning to account or rationale. Reproduced from https://en.wikipedia.org/wiki/Outline_of_epistemology [Accessed 9/3/2019]

In scientific research this "principle of reflexivity" is lost because scientific research requires "metaphysical realism" in that it cannot tolerate a situation in which there are two contradictory propositions as research outcomes. In scientific research it would not be possible for both to hold validity. So let us consider that two action researchers are doing the same research under the same circumstances and the results data are similar with the same interventions but the research reports differ in that the conclusions drawn and recommendations made differ. According to "metaphysical realism" either one or both reports is/are false and the recommendations are overlooked. Therefore, Heikkinen et al., (2012) claim that in scientific research, ("metaphysical realism"), the spirit of qualitative research is lost as it seeks only one true description of what it defines as reality. Two case studies of AR are detailed by Heikkinen et al., (2012) and the authors of the case studies both uphold that in order to empower AR the researcher must cope with uncertainty and conflict and that as a change agent the researcher has to take risks and cope with chaos and uncertainty. It may also become a very uncomfortable task to point out the negatives to the working community (or stakeholders in your research) at the risk of becoming marginalized and may result in a tendency to retreat from new ideas.

Coping with uncertainty is part of developing experimental educational practices and this often requires the formulation of the relevant problem or a question (McNiff, 2017). Adapting to a majority opinion and yielding to social pressure is easier than remaining a critical thinker and a change agent.

The five principles for validating AR (Heikkinen et al., 2012) are invaluable guidelines as they have been developed over time. They can lead us through the whole research process. AR is a practice that should include physical, sematic and social dimensions. There is a connection between the narrative and AR in that AR can be reported in the form of the narrative: with a beginning, middle, end, characters, plots etc. forming the AR narrative.

Kinsler, (2010), comments on the slowdown of AR, particularly educational AR, and remarks that it has fallen short of what it could have potentially delivered in the form of social justice. It refers to this shortfall as being attributed to several factors but some are identified as more prominent than others. One of the claims made is that many educators are often guilty of using AR as a means of increasing practical professional efficacy, in that produced results are as desired or intended. It is worth noting here that the results reported from this research and presented case studies are both qualitative and quantitative and therefore factual. It is said that AR is used as technical tool to facilitate a particular teaching technique and even to justify policy. It is also said that little attention has been paid to practical outcomes of educational AR and it is suggested that it is time to rethink the range of criteria used to determine what counts as unrestricted AR. It is claimed that undue attention is given to the practical outcomes of educational AR. Earlier work by Carr and Kemmis, (1986) was seminal in asserting practical problem solving of AR in education and its critical use by classroom practitioners. This decline points to the separation between research and action and theory and practice and a merge with traditional and orthodox research paradigms, that it was intended to replace. Smith, (2005), on commenting on conditions in Australian and UK educational institutions states that they have been forced into "highly specified outcome-driven curriculum frameworks" along with reform developments. The work of Kinsler and the statements made in her publication, reiterate those made by Carr and Kemmis, (2009). Clearly, some of the statements asserted by Kinsler appear quite controversial and researcher need be mindful of it in the view of the case examples used. It is therefore the researcher's intention to use the five validation principles for AR (Heikkinen et al., 2012).

Jensen, (2015), reports on an AR project which addresses gaps in the education of engineering undergraduates to enable them to develop knowledge in sustainability and leadership. The applied methodology is described as "mixed method action research philosophies" which included two widely accepted fields of AR, exploratory and participatory AR, both common in education (Joy, 2007). The aim of the project was to close the gap in knowledge through AR in order to meet certain educational objectives. The first of these was to consolidate education and sustainable development and the second was to establish a learning collaboration by linking traditional STEM subject learners to community projects that require multi-disciplinary input. Although many engineering disciplines have subtly incorporated sustainability within undergraduate courses through relevant themes within modules, there appears to be little evidence of a comprehensive approach, as is required, for creating a more sustainability-focused curriculum. This could entail integration of different modules from various educational stages, development of intercultural-multidisciplinary skills and environmental literacy (examples are given by Martins et al., 2006 and Fenner et al., 2006). Curriculum delivery in this manner, outside the traditional classroom, would offer rich contextual experiences. Peer and Stoeglehner, (2012) recommend that HEIs should offer customisable educational programmes if they are to be agents of change. To do this, they suggest involving local and regional communities. An alternative would be to combine traditional engineering topics and social justice topics as has been described by Riley, (2011), using an example in the context of thermodynamics. The importance of community involvement as part of the curriculum is illustrated by Lucana et al., (2010), who suggest that engineering problem solving via technical problem solving skills alone is inadequate in the context of the wider sustainable community and its development.

Important issues of academic integrity are addressed by Levin, (2012), in defence of certain adverse criticism from the research community outside AR. It is emphasised that academic integrity in AR is essential for shaping research of high rigor. Indeed, rigor is fundamental in research.

The academic integrity of AR depends much on being able to answer pertinent problems whilst also rigorously securitize experiences and communicate research-based findings. The challenge lies in the combination of empathy and political involvement coupled with critical and reflective research whilst also stepping back and being objective about one's own experiences. This necessary distance between involvements in a change process with the aim of explaining the phenomenon is of the essence of building integrity in the research activity in AR. The critique from outside the AR community is simply based on the different ontological and epistemological position of AR. This, claims Levin, (2012), is both "unfair and dishonest" and responds to it with reasoned arguments. AR faces real-life problems in a holistic situation and the knowledge generated through the research process depends on the problems at stake. Relevance of the research emerges on the basis, as Dewey, (1938, 1991), put it,

> *"an undetermined real life situation that is made determined (understood or explained) through (active manipulation) research activity"*.

Levin, M., (2012) covers five factors that support high rigor in writing scientific texts for communicating research findings: ***research partnering; controlling biases; standardised methods; alternative explanations and trustworthiness***. Utilising and documenting these factors, or warrants for rigor, would imply credible AR with integrity, claims Levin, (2012). The five factors that support rigor are explained as follows:

Research partnering – as individuals, researchers have their biases (often based on personal values and political preferences that guide perception) and as such may not be more objective than other persons in society, but professionally in perspective of the research process they have to cope with 'distortions', systematically. For this reason, it is advocated that working together with a colleague is definitely of value because it offers the opportunity for interpretation and discussion of solutions prior to decisions. The value of such collegial discussions cannot be overestimated claims Levin, (2012) as this addresses the possible issue of ***controlling biases***. I propose to do this through collegial discussion as will be indicated by the detailed case studies which have been published in joint authorship.

Standardised methods – In AR, research methods may use either quantitative or qualitative. The AR must be aware of the limitations and possibilities in claims made based on the applied methods. This would imply that analysis of data must be aligned with accepted procedures. The case studies that will form the core of this research will gather data through a combination of analysed questionnaires, student comments and analysed assessment results.

Alternative explanations – A means by which to create critical detachment for the action researcher is by developing alternative explanations and being able to come up with more than one model for explanation. This may require discipline in forcing oneself to think alternatively. This in itself is a creative process which should continue as long as new models of explanation emerge. Strong predispositions from the researcher may cloud out many possible explanatory models claims Levin, (2012). Developing alternative explanation models greatly improves the quality of the research. Although case studies I will draw conclusions, I also propose to explore possible reasons for certain research outcomes.

Trustworthiness – The factors already listed, if considered will create reliable and valid conclusions in research. The main argument for partnering is awareness of one's own biases, standardised methods and alternative explanations. If the factors are applied to AR than integrity of the research results from the rigor. The findings from AR must stand up to scrutiny of reliability and validity. It is for this reason that I propose to apply two cycles of the AR spiral for two of the case studies.

Hynds, (2008), explores the implications of 'open communications' in AR projects as advocated by Kemmis, (2006). Hynds puts forward a case whereby engaging the voices and perspectives of others, besides the action researcher, such as parents and community members (and possibly a small number of our own students who may choose to be deliberately objectionable to new methods of delivery), can have implications which can be detrimental to the research. This is because barriers to maintaining critical dialogue and collective enquiry can become evident. This is because there may be various stakeholder groups with lack of will for change due to differing vested interests. Critical collective analysis which engages diverse stakeholder groups can uncover hidden interests, power relationships and dominant discourses that can effect educational outcomes, argues Hynds, (2008). Conflicting interests need to be overcome for AR to implicate unbiased change.

Kemmis, (2006), Identifies inadequate forms of AR, whilst putting forward the argument AR must be capable of "telling unwelcome truths". He makes reference to schooling and the interest of education. AR often “lacks critical edge” claims Kemmis, (2006). AR must reassert a connection between education and emancipatory ideals in order to allow educators to address contemporary challenges. Kemmis, (2006), revisits his original work (Carr and Kemmis, 1986) of *Becoming Critical*, and comments that much of the AR undertaken since the landmark publication took more technical approaches to AR by educational action researchers, rather than a critical form. He reaffirms the original advocacy of critical AR and critical social and educational science in Becoming Critical in order to provoke changes from within educational establishments. Three key messages are listed regarding Kemmis’s critique of educational AR:

1. ‘Research’ is a matter of addressing important problems in thought and action, or theory and practice. In education, the implications are for the good of learners and society as a whole. One needs to be ’critical’ for this reason.
2. In educational AR, projects and themes may cross boundaries beyond the immediate educational environment.
3. The third and probably the most important point is that of critical participatory AR which explores practice in a deep, rich way in order to bring to light and encourage communication to explore practices, outcomes from various standpoints and perspectives.

Kemmis (2006) claims unwelcome truths should be told by action researchers and practitioners. By avoiding such truths (particularly unwelcome truths), is not the kind of research needed to transform practice. If it tells no unwelcome truths, then it is unlikely to be critical research. In education, caution about encountering uncomfortable truths may lead (and has done) away from investigating some of the most substantial themes and issues confronting education and our societies today. Kemmis, (2006), states that this is how he would wish for AR to be today in order that it engages with substantial problems facing both society and education, in changing times. Therefore, the practitioner action research has the capacity to be open communicatively and explore “the way things are” for open question and exploration. It should aim for understanding reality and exploring it in order to transform it. It requires truth-telling, both with respect to the truths that arise from our findings and the methods used to arrive to them. Importantly, it must also require for critical evaluation of how I have done the research and whether findings are justified by methods.

In Edwards-Groves and Kemmis, (2015), the authors describe the operations of network known as the Pedagogy, Education and Praxis (PEP) network which has brought together action researchers from several countries. The researchers, who subscribe to the network, are investigating the nature, traditions and conditions of pedagogy, education and praxis and how they are understood, developed and sustained in the context of different nations and educational settings. The justification for the network, which was set-up in 2005, was based on aspirations for transforming educational practice in an era of the emerged performance driven audit culture (Comber and Nixon, 2011). Comber and Nixon, (2011), report on an era of global educational changes in which educators are increasingly becoming locked in regimes of standardisation, managerialism, accountability, bureaucratisation and performance drivers. The Pedagogy, Education and Praxis (PEP) network emerged in response to such contemporary conditions, to answer back. The PEP network appears to be one amongst many similar initiatives that address such issues in an international programme focussing on AR. Basically, it has basically formed a forum for international research partnership to flourish, engaging people from different cultural, political and intellectual traditions for mutual understanding on issues facing education. The network claims to have created new research activity with continued new educational thinking, debate and discussion. These may be small moves but they are answering back to the de-professionalization of education, claim Edwards-Groves and Kemmis, (2015).

2.12 Review of engineering action research articles

In Olds et al., (2012), an editorial article reports on the ever-growing need for collaborative action research in engineering education As in previous editorial articles in the Journal of Engineering Education, a strong case is presented for implementation of practices, which would enhance engineering education through interventions, many of which have been proven to enhance teaching and learning. It is argued that the results of engineering education research have, for the most part, not been broadly adopted in the engineering classroom. Reports by various bodies such as the National Academy of Engineering, the National Research Council and the National Science Board have all presented compelling visions for the future of engineering education yet few suggestions have been made on how these can be achieved. In a 2012 report by the US President's Council of Advisors on Science and Technology (PCAST), the following recommendations were made:

> *"1. catalyze widespread adoption of empirically validated teaching practices;*
> *2. advocate and provide support for replacing standard laboratory courses with discovery based research courses;*
> *3. launch a national experiment in postsecondary mathematics education to address the mathematics-preparation gap;*
> *4. encourage partnerships among stakeholders to diversify pathways to STEM careers; and*
> *5. create a Presidential Council on STEM Education with leadership from the academic and business communities…"*

Several other institutions, as well as individuals, with authority to be vociferous, on the future of engineering education such as the ASEE (American Society for Engineering Education), (ASEE, 2011, 2012, Streveler and Smith, 2010, Streveler and Menekse, 2017) make recommendations along very similar lines which are for:

- The expectation of career-long professional development for faculty staff in order to evolve engineering education to meet future needs of graduates
- The expansion of collaborations between engineering, other disciplines, and other parts of the educational system
- Continued efforts to make engineering programmes more engaging and relevant as well as welcoming
- The increase of resources for engineering teaching, learning and educational innovation
- Raise awareness of proven principles and effective practices
- The conducting of periodic self-assessments to measure progress at the institutional and community levels.

Olds, et al., (2012), also raises the question as to how we can develop learning tasks, which are both engaging and address common-held misconceptions on delivery methods. This clearly offers opportunity and need for collaboration between education researchers and engineering faculty. The 'Innovation with Impact' report (ASEE, 2012), suggests that active learning and other evidence-based interventions are not practiced despite the body of research showing them to be effective. Most cited work affirms the need to use "empirically validated teaching practices". The question is posed as to whether change is wanted, despite the body of evidence, as to "what works" being known as there are still barriers to implementation (both at the individual and institutional level) of these practices, especially in the engineering sciences. The question exists as to how these barriers are addressed.

2.13 Engineering education research –Review of activity based learning (incorporating experiential learning and problem based learning)

The work of Niever et al., (2018) describes an example of a holistic educational model in which undergraduates engage in product development Activity Project within what is referred to as a Virtual Idea Laboratory. The objectives of this are similar to the Integrated Concurrent Engineering Education (ICEE) concept in that it aims to integrate the understanding of product development and the competencies associated with it along with interdisciplinary content. A holistic education model which is case-based fosters development of diverse competences for training of undergraduate engineers. Niever et al., (2018) describes one example but falls short of proposing further scope. The example is quite elaborate and would call for much resource and coordination.

There are several important aspects to this work including the requirement for teamwork for success and recognising the need for interdisciplinary subject integration. It makes reference to Bloom's revised taxonomy in order to gauge competencies leading to a revised approach to university education. The case is based on a major action learning project introduced as part of the curriculum. It is a major activity which, in the publication, is referred to as a "design method internship" in which students consolidate theoretical knowledge whilst building up important skills such as social whilst team working and soft skills whilst being creative. It starts with knowledge building through conventional lectures, followed by tutorials and eventually leads to a workshop centred case-based project. Through Action Learning, students form “learning communities” for discussing and resolving arising problems.

In Niever et al., (2018) the action based project attempts to bring together through an interdisciplinary process students from two separate postgraduate course, one being Mechanical Engineering students and the other International Management and Industrial Engineering students. It entails the application of a major project whilst the researcher aims to apply a similar concept (ICEE) with a series of smaller activities within the same course (on a micro rather than a macro basis).

The work described in Niever et al., (2018) aligns in a similar manner with that I aim to achieve as part of this action research, but with a fundamental difference, to be more pragmatic in order to interweave such Action Learning within a wider scope of the curriculum.

In Rossiter, (2011), the author explores several technologies which can potentially enhance engineering education. The publication makes valuable contributions to the subject of enhanced e-learning for engineering teaching and learning. Rossiter argues a strong case for academics to proactively explore the potential of technology for enhancing teaching and learning with relatively little effort and expense which can result in significant gains in quality of education. Importantly, Rossiter recognises that the main ingredient in achieving this is the imagination for this. The reason what Rossiter’s work is significant to us is that he recognises one of the main objectives and a gap of the work presented here. There are many points made in his publication that ring true in the researcher’s own experience. One of these points is the recognised tension between the need for a quality educational HE provision whilst also producing quantities of high quality research. He identifies the shortfall in developments and publications in developments for teaching and learning, particularly for the engineering and technology sector. As a consequence of demographics within academic circles (i.e. the conflict between quality education and research) is that the use of modern technology goes much unexploited. There are huge opportunities for doing things differently, as Rossiter describes through a number of novel examples in which technology enables richer engagement learning experiences, whilst also saving in staff time. In fact, the key to the adoption of such revised practice is by ensuring that preparation is relatively easy and staff time (in delivery, feedback and assessment) allows for efficient use. Any such practice must nurture the natural inquisitive instinct of learners. The examples given by Rossiter focus on VLEs, electronic response systems, computer aided assessment and peer assessment. With regard to peer assessment, mention is given to WebPA (Web Peer Assessment), a system that was initially developed by a team at Loughborough University. WebPA is a software provision with the principle aim of automating and giving rigour to mechanisms of peer assessment whilst accounting for individual student contribution to group assignments. Such systems are not yet well integrated within most VLEs for most institutions. Usual practice within VLEs appears to be evidence based where students are required to deposit individual contributions in the form of a log or discussion board (a practice which has been prone to failure). The use of WebPA has been recommended for future exploration for this research and therefore is outside the scope of the presented case studies. It is however recognised for its great potential in group work, as is the work of Belbin, (1981). Other technologies that Rossiter states to offer great potential include podcasting of short lectures (covering key points), online quizzes, animation, imaginative use of discussion boards, student generated audio for learning and standard commercially available Graphical User Interfaces (GUIs) such as MATLAB. As it is recognised that students have different learning styles, a variety of learning resources helps individuals to find something that helps them. However, studies have shown that just because excellent learning resources are offered, it does not imply that leaners will use them (Rossiter and Rossiter, 2004).The key message that can be extracted from Rossiter, (2008), is that in general, technology is often underused in engineering education because staff cannot appreciate that with little effort and imagination they can produce high quality resources that can make significant differences in the student learning experience. A variety of innovative yet accessible approaches has been suggested for different contexts. Such an encouraging approach should be embraced by all academic staff in order to enhance delivery of their subject specialism. This need not be neither expensive nor time consuming. There is an argument that the simplest and least difficult technology delivery strategies are the most successful ones. This is based on that they are more likely to be implemented and sustained. The resources can be minimal in that all that may be required is a

VLE (which is a provision that most HE providers have), a web browser, possibly a server for audio recordings by both staff and students and of course, some imagination and creativity. Rossiter (2008) makes a valid point whilst proposing an obvious solution. However, he overlooks the desire and impetus lacking within much of the academic community that is highly driven by research outputs.

One of the points made by Rossiter, (2011), is that it becomes difficult and potentially very fraught to gauge changes in assessment performance between different cohorts of learners due to disparities (such as the varied profiles in individuals that make up the cohort from year to year). The researcher also agrees with that, and as a result of this may pose a similar risk in our own research.

In Van Hanh and Hop, (2018), the authors consider a case for a field trip to a hydropower station as part of experiential learning prior to the start of an undergraduate course in electrical engineering. They address two key research questions, which relate to 1. The students' perceived benefits as a lead in to their undergraduate studies and 2. The impact that the field trip would have in their learning process of power generation. Dewey's theoretical framework was used for integrating the field trip as part of engineering education. The trip was a compulsory part of course induction and was reviewed annually for improvements. There were several class-based activities, both prior and post the field trip for reflective learning. Success of such experiential learning was measured through a questionnaire containing general questions relating to perceived benefits. The results were positive though possibly somewhat pre-mature at this stage of the course. The highest scoring question related to "passion and desire to become a professional engineer", following the field trip. The authors conclude on a" very effective pedagogical strategy" and "a catalyst allowing first-year students to get acquainted and transition to engineering education". Although supportive of experiential learning, experience denotes that there are potentially strategic problems associated with large groups and health and safety. For this reason organisations are often far from being accommodating. Students with a keen interest in their chosen course tend to joint societies (such as the engineering society) for extra curricula activities of which industrial visits are included.

Abele et al., (2015), makes reference to 'Learning Factories'. The origins of these lie in a state funded project in the USA, dating back to 1990s and that is when the term was coined which referred to interdisciplinary hands-on engineering design projects (within academia) with strong links and interactions with industry. The application of the concept can vary widely but Abele et al., (2015) document several scenarios. The earlier model of learning factories emphasized the hand-on approach for gaining experience based on knowledge accumulated during engineering education to solve real problems confronting industry or design/re-design products to satisfy identified needs. The concept has spread with wider adaptation within Europe (Wagner et al., 2012), taking many forms of facilities and varying in size and sophistication. The prime objective remains the same, which is, to enhance the learning experience of learners in areas of knowledge. The word “Learning” rather than teaching accentuates the importance of experiential learning as research has shown that learning by doing leads to retention and application possibilities than more traditional educational methods (Cachay et al., 2012). “Learning Factories” are therefore effective in developing the participants’ competency in ability to master complex, unfamiliar tasks. There are great varieties of learning factories catering for a wide variety of learning environments with examples cited by Abele et al., (2012), that include environments in which companies and learners acquire competence to boost sustainable productivity and Lean manufacturing. The training environment replicates a particular industrial scenario or may even be the actual manufacturing environment where participants can discover lean manufacturing principles and methods and directly apply them without risk of failure or cost pressure. The authors conclude by appraising Learning Factories and recommend their further expansion. They also recommend that they should be able to measure learning success in a simple but valid way and that they should have a wider association with innovation, be it in product or process technologies.

As an example of a learning factory, and of relevance to own research, within a local geographic proximity is the Process-Manufacturing-Centre housed within Kirklees College (see, https://www.kirkleescollege.ac.uk/the-college/our-centres/process-manufacturing-centre/). This was specifically developed to serve the needs of a thriving local process manufacturing industry (particularly in chemicals manufacturing) which has historically encountered difficulties in recruiting and retaining personnel with the required skills set.

Inevitably, such centres, or “Learning Factories” are costly to commission and maintain, especially during times of austerity. It is now often the case that they rely on the generous sponsorship of local industry. What is fast emerging as an alternative to such centres, in a digital age, is the application of Digital Twins that refers to a digital replica of physical assets (the digital twin) of processes, people, places, systems and devices. Live interaction is possible via a Virtual Reality (VR) headset to allow the learner to explore an environment with ‘what if’ scenarios. This has been successfully used in-house at Siemens plc for training personnel in optimising production facilities as well as design for manufacturability (Fryer, 2019).

An integrated hands-on approach to manufacturing and engineering education by adaptation of a Learning Factory (LF) approach is also discussed in Ssemakula and Liao, (2006). The authors report on coordinating different subjects from a curriculum in order to enable students to generate detailed production drawings, produce detailed plans for the required components, manufacture them and then assemble them into the finished product prior to building and testing the miniature engine. The activity is reported to have been incorporated as part of an existing course, rather than developing a new one, consequently minimising the effort and disruption whilst integrating the activity within an existing programme of studies. The activity is built around core modules such as Graphics, Design and Manufacturing processes. Students are introduced to the LF at year 1. The objective is to create an integrated practice-based engineering curriculum that balances analytical and theoretical knowledge with factory hardware facilities for product realisation. The level of student satisfaction was gauged at the end of the semester through a feedback questionnaire containing questions on a number of issues relating to the adaptation. The questions related to number of practical sessions, practical activities, group work, satisfaction with facilities, group work, time allocation, project realisation and overall satisfaction. The qualities of learning outcomes or the depth of achieved knowledge were not assessed as a result of this integrated activity.

An alternative model of experiential learning experience from Learning Factories (Adele et al., 2015) is described by Mork et al., (2016). The authors report on a case where a university and industry have collaborated for the creations of a learning environment. The learning environment was based at a company who designs and partly manufactures a range of furniture. In an effort to reduce costs they had considered the viability of in-house robotic assembly. Three objectives had been set for the industry based collaborative venture which were:

1. For a collaborative learning environment and efficient working methods
2. Cultural changes within the university
3. Project goal setting and execution.

A small interdisciplinary team of students from two different engineering departments (automation technology and Product and systems design), were seconded within the manufacturing enterprise in order to build a prototype, and scaled down, robotic assembly cell. This would prove a valuable ‘learning by doing’ process. The team were located within the company’s design office within close proximity to the coffee vending machine as this would elicit dialogues with designers which were essential for knowledge exchange and creative processes required for problem solving. It also served as a means of creating ownership within the organisation. Furthermore, the students were also gaining knowledge about customers’ demands, product attributes and also gained access to facilities such as 3D printing and workshop facilities. They had gained by being engaged in interdisciplinary work which required holistic thinking in product development and production. The learning collaboration was bidirectional as academic staff was also involved along with technical experts from robot supplying companies. The growing professional networks had triggered new interplays. The fact that students had originated from different departments resulted in the removal of barriers between the two faculties. The learning model is as illustrated in figure 2.13.

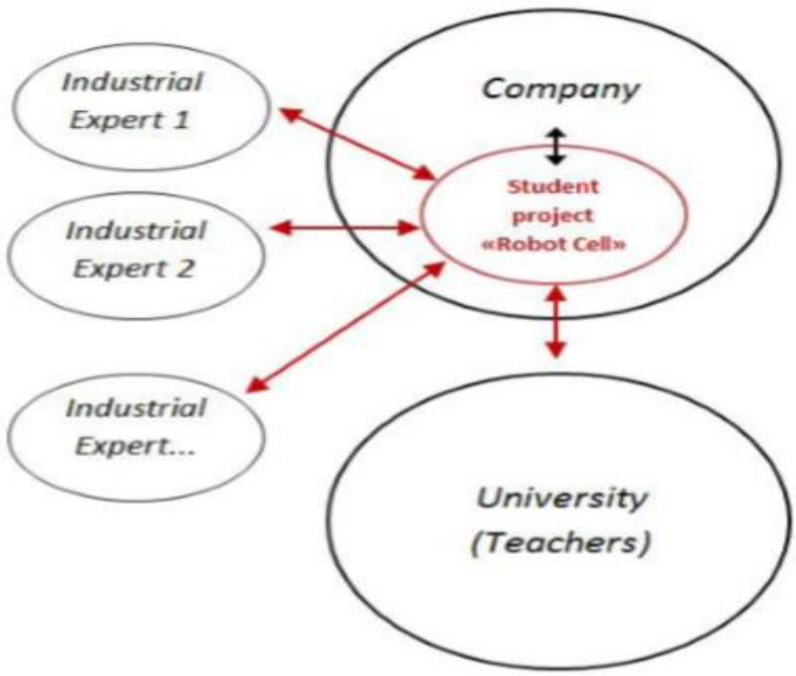


Figure 2.13: Facilitating the learning environment as represented in Mork et al., 2016. The arrows indicate knowledge exchange flows. Reproduced from, (Mork et al., 2016)

In Barrows, (1986), taxonomy for Problem Based Learning (PBL) is presented in which the author presents a convincing case that PBL does not refer to a specific educational framework. PBL can be presented in several ways depending on the design of the educational method employed as well as the skills of the facilitator. The differences in delivery types of PBL are outlined with examples which refer to medical education and training, as the author is a medical practitioner as well as an educator of medical practice. The presented taxonomy is intended to facilitate awareness in differences of delivery in order that an appropriate taxonomy is applied as a problem-based learning method, with the student cohort in mind. Although a wide variety of educational methods are referred as being PBL methods they address quite different educational objectives. Different forms of PBL are applied in practice but Barrow’s taxonomy helps in that it identifies the value of different methods in alignment with the learning objectives. He defines the precise taxonomy in terms such as:

“SCC - Structuring of knowledge for use in clinical contexts

CRP - The developing of an effective clinical reasoning process

SDL - The development of effective self-directed learning skills

MOT- Increased motivation for learning".

Barrows states that there are other objectives that can be accomplished through PBL but the ones listed are of primary importance in establishing an effective and optimum mix for the PBL application. The given example clarifies this if used in conjunction with Table 2.5.

Example in medical practice: Students may be given a case history brief account of it containing a summary of the key facts in an organised manner (solid circle) and their challenge is to decide what is going on with the patient and what should be done based on the given facts. Alternatively, they may be given a presentation of the problem and required to assemble the key facts through free inquiry by asking the right questions and through clinical reasoning (Smiling black circular face)

Table 2.5: Variables in problem-based learning methods. Adapted from (Barrows, 1986)

●	Complete case or brief open account is given
☻	Partial problem simulation
○	Full problem simulation (free enquiry)
■	Teacher-directed learning
□	Student-directed learning
◘	Partially student and teacher directed

In a case-based lecture (see table 2.6) students are presented with either a detailed or partial case prior to a lecture which highlights the material to be covered (this could take the form of a podcast). Their prior study challenges clinical reasoning and they are required to analyse the case using prior knowledge. New knowledge is provided later thus structuring new knowledge in a subsequent lecture. There is no self-directed learning unless the learner has the curiosity to seek additional information for clarity.

Table 2.6: Example of a case-based lecture in PBL. Adapted from (Barrows, 1986)

			SCC	CRP	SDL	MOT

■	●	Lecture-based cases	1	1	0	1

The term PBL can therefore cover several frameworks and each addresses different objectives to varying degrees. In the given example the objectives of SCC, CRP and MOT are covered but only to a value weighted at 1 on a scale of 1 to 5. The descriptions and evaluations used in any PBL method must be evaluated claims Barrows. Depending on the educational objectives, the method that fits best may be chosen. Interest in this article lies in certain parallels between engineering and medical education.

Perrenet et al., (2000) explore the sustainability of problem based learning (PBL) for engineering education and its viability as an innovative tool in engineering teaching and learning. Comparisons are made and analysed between medical and engineering implementation. As an alternative to PBL, the authors also consider project work (project based learning) as a strong alternative to PBL, especially during later years of study. The trend towards student-centred learning approaches is clearly identified by the authors who focus on PBL and project based learning, in particular. Other educational methods such as lecture and skills based delivery is not snubbed in favour of student-centred learning techniques as they have a place in support of PBL, as an example. The key question that has been addressed is whether PBL is a suitable overall strategy for engineering education regardless of the domain involved. In addressing this key question Perrenet et al., (2000), firstly identify that the three main objectives for education should simultaneously achieve the following:

1. Acquisition of knowledge that can be retrieved and used in a professional setting;
2. Acquisition of skills to extend and improve one's own knowledge;
3. Acquisition of professional problem-solving skills.

Perrenet et al., (2000) cite the work of Barrows, (1984) as a landmark publication in which the purest form of PBL is defined. This is described a cyclic process consisting of three phases. In the first step, students must be presented with the problem, instead of facts and theories. Professional reasoning skills are developed and learning needs are identified (gaps in knowledge in order to negotiate the problem) in conjunction with the tutor. The next phase entails self-directed study, motivated by the preceding phase. This may also entail delivery of specific subject topics (though class delivery or self-directed study of manageable 'bite size' knowledge). The cycle closes through the third phase of applying newly gained knowledge to the problem and identifying what has been learnt. Overall, the problem should provide a challenge to the reasoning skills and focus on the learning process. It therefore considers 'metacognition' – awareness of knowing about what there needs to be known. Despite lecturing being an efficient and easy way of parting with large amounts of knowledge, it does not consider students' ability to absorb the information and use it later in a useful manner. Based on constructivism, knowledge is structured in interrelated networks of concepts or relationships between new information and prior knowledge of a subject, which is what makes it more useful and transferable.

Distinction is made between PBL and project work, though both are based on self-directed learning and collaboration between learners. What they have in common is that both methods encompass multi-disciplinary problem solving as opposed to mono-disciplinary of conventional education. Generally, projects are larger, are of greater duration, and may result in tangible products. The key difference as defined by Perrenet et al., (2000), is that whilst project work is directed to the application of knowledge, PBL is more directed to the acquisition of knowledge and therefore requires greater intervention by the tutor or facilitator.

As regards to the original question on the sustainability of PBL as an overall strategy for engineering education, some very useful conclusions have been arrived at by Perrenet et al., (2000). Backed by practical examples of course structures for both mechanical and biomedical engineering, as well as citations of earlier work, it was concluded that PBL could be successfully applied in engineering education programmes. During earlier years of study on undergraduate programmes, it is claimed to be largely justified on the basis of motivational reasons but cognitive reasons also play an important role throughout. The emphasis is more on application and integration of knowledge rather than on acquiring wide and deep knowledge.

PBL, ascertain the authors, can be further developed in engineering education to bridge gaps between theory and practice in a gradual way.

What needs to be recognised that certain engineering topics are characterised by hierarchical knowledge structures and complex problem-solving, in which case, the PBL sessions become more involved (with teacher-guided discussions, separate practice with supervision, multiple sessions, structured group work etc.). Learners appreciate group work and the process of discovering new knowledge applications. For a partial strategy of PBL on undergraduate courses, this has to be carefully planned and integrated in a consistent design of the curriculum.

Horgan, (2003), reports on variances in lecturing in order to enhance learning. The author's work is based on reported best practice, what is said to work and what doesn't, with case examples. Some key issues are identified in this article such as the growth of wider participation in HE that has brought a broad spectrum of ability from diverse backgrounds. Another issue identified is associated with disruption in lectures, such as that created through the use of mobile phones and other devices. There are several issues discussed in this article that ring true and of relevance to the proposed research. Horgan, (2003), quotes McKeachie, (1994), who said on the subject of factors that present an enormous challenge to academic teaching staff in HE, they are expected to:

> *"combine the talents of scholar, writer, producer, comedian, showman and teacher in ways that contribute to student learning"* (McKeachie, 1994)

On the basis of this statement McKeachie considers ways in which the lecture method can be used to promote student learning by making it more effective. The key way to this is to adopt an approach in which learners take a more active part in class. Despite the critics, lecturing as a teaching method remains the most widely used method in HE as they provide a cost-effective means of teaching large groups of students. Economics aside, it is still argued by many (teachers and learners) that it remains an essential part of any course, backed with cited compelling pedagogic reasons, often based on appropriate structured delivery (Cashin, 1985). (McKeachie, 1990), concluded that where active discussion is used; teaching is effective, provided that the following are measured:

> *"• retention of knowledge after the end of a course*

- *transfer of knowledge to new situations*
- *problem solving and thinking*
- *attitude change"*.

This was also supported by Bligh, (2002), who carried out a comprehensive review of the literature. According to Ramsden (1994):

> *"Active engagement, imaginative inquiry and the finding of a suitable level are all much more likely to occur if teaching methods that necessitate student activity, student problem-solving and question-asking and co-operative learning are employed."*

Where the traditional lecture falls is when learners are allowed to take a passive role with little or no opportunity for active learning. This is because in the opinion of many lecturers this is the most effective method of 'covering the material', yet to the dissatisfaction of the learners who only see the material as remaining 'uncovered'. There are some good suggestions made by Bligh, (2002), which include the introduction of novel points and/or contrasting approaches partway through the lecture. According to Bruner's theoretical framework, (Bruner, 1966), learning is an active process in which we construct new ideas or concepts based on current/past knowledge. This would imply that the role of the teacher is to present information in a format that can be accommodated in the learner's current state of understanding. A key question is how I can achieve this in a way that attention levels are maintained whilst active learning takes place whilst the lecturing technique is improved. Lecturing is to be less like a traditional didactic style in which learners have a passive presence within a rigid session where routine knowledge is transmitted. General recommendations are listed by Horgan, (2003), which have been cited from various sources. The author has also listed several ways in which to vary student activity in lectures. Of these, showing a DVD clip or AV streaming part way through delivery, presenting a brief set of multiple choice questions, and instructing in what to look for prior to viewing, are all included suggestions. In conclusion, Horgan, (2003), recommends that anyone contemplating a change in delivery from a traditional lecture, to adopt a more interactive approach in a step-by-step change and not be deterred if it doesn't work immediately. Reflect on why and try again. Although this sounds like a plausible solution, younger teaching staff, which are new teaching and learning, may be deterred if things go wrong and maintain traditional delivery within their own comfort zone.

In Overton, (2003), Key aspect of teaching and learning which are more specific to engineering and experimental sciences, are discussed. This article contains several case studies within relevant subject areas. What makes disciplines such as engineering (and experimental sciences) different from many other subject areas is that the curricula may often be largely governed by a professional governing body (such as the Institute of Engineering and Technology or the Institute of Mechanical Engineers). Even the teaching and learning methods are often determined by the governing bodies states Overton, (2003), with examples given for practical work and projects. How and what we teach in engineering disciplines is therefore important. Overton, (2003), identify the challenge of recruiting and retaining undergraduates in STEM subjects as they are seen as ‘difficult’ and ‘unattractive’ to young people. Some teaching and learning methods are particularly important in engineering subjects. The author has correctly pointed out that delivery of curriculum on engineering courses tends to be predominantly linear in nature. An example is when certain year 1 module (often know as foundation level module), underpins basic concepts before further study can be considered. What follows in subsequent years are intermediate and honours level modules. Although tutorials are still commonplace on engineering courses, these pose their own difficulties due to growing group sizes, where engagement and participation can be lost. Overton, (2003) suggests problem-solving as an aspect of small group work with open-ended or ‘fuzzy’ problems with no single correct answer. The author identifies PBL as a relatively new development in engineering education. It is emphasized that PBL is different from ‘problem solving’ because in PBL the problem is encountered before relevant knowledge has been acquired. This forces the learner into a situation where there is a need to acquire the problem solving skills (be it collectively through collaborative teamwork or by other means) and also acquire the knowledge (often through self-directed learning, but not exclusively). If the problem in hand requires certain knowledge, then the learner may become more focussed in acquiring this knowledge whether by self-direction or tutor disseminated. Although relatively new to engineering, PBL is well established in medical education and has spread across other practice-based and health-related disciplines. The following are cited by Overton, (2003), as benefits of PBL:

- Produces better-motivated students
- Develops a deeper understanding of the subject
- Encourages independent and collaborative learning
- Develops higher order cognitive skills
- Develops a range of skills including problem-solving, group working, critical analysis and communication.

What changes in the delivery of the engineering curriculum when more PBL is introduced is a less linear delivery, in order to equip learners with the knowledge to deal with the problem in hand. In PBL the knowledge can be acquired though self-directed learning provided that direction is given by the facilitator (or mentor/guide). The role of teacher thus changes to one of facilitator. The problems have also to be matched to learning outcomes. Of the identified shortcomings of PBL identified is the lack of rigour as less subject matter is covered as compared to a lecture-based delivery. The correct facilities are also required for PBL to work, such as flat seminar rooms with moveable furniture and greater effort is required from academic staff to 'invent' new and suitable problems. Overton, (2003) cites a PBL case study at Manchester School of Engineering where students progress through a programme of study by solving simple, contextual problems. The problems graduate in terms of difficulty in that, at year 1, they are designed to reinforce the learning process rather than to ensure coverage of the material. As students develop their learning skills, later in their course, problems become more knowledge focused. Group work is at the core of their PBL and task scenarios can range from a day to several weeks in duration. Other aspects of engineering curriculum delivery are discussed by Overton, (2003) including project work, which forms a key aspect, especially at final year and postgraduate level. Skills and employability are also discussed and key skills (in accordance to subject benchmark statements on transferrable skills) are identified as follows:

- Communication skills
- The use of Information Technology

- Numeracy
- Learning how to learn.

Problem based learning as a pedagogical means for supporting students' knowledge acquisition and the problem-solving capacity were examined by Mioduser and Betzer, (2007). Technological knowledge construction was examined following the project based learning interventions in order to determine whether learners performed better in a standard HE entry examination. The research was applied to groups of learners of later high school age and consisted of a range of technology based projects from which the students could choose from. The objective of the research was twofold. Firstly, they wanted to determine whether students would acquire greater knowledge and technological problem solving skills. Secondly, in recognition that academically high-achievers in high-schools tend to generally shy away from studying technology based subjects at a higher level, wanted to see whether they could inspire learners to reconsider, following project based learning activities. The control group consisted of 60 students and the experimental group of the same number, all from a technology bias high school in Israel. All students were due to take their national matriculation exam at the end of year. Each of the control and experimental groups were sub-divided into three further groups and given a choice of projects ranging from designing and constructing a climbing robot to designing a swimming pool filtration system. The authors report that after the learning process comparisons were made in performance of the groups and claim that there was significant improvement in the project based learning students' exam performance. They also report improvements in problem solving skills and changed attitudes towards higher level study of STEM subjects. They were now more enthusiastic about going on to further study of STEM subjects. There is little information provided on the early educational background, the educational system and cultural attitudes of the pupils who were the subjects of this research. The subjects were also of a younger age group than the groups that this research project focuses on.

In Beaty, (2003), the author covers various types of experiential learning and how such learning is supported. It is recognised that, the training and education of certain professions, such as in medical practice, takes place concurrently in that academic study is undertaken alongside supervised practice in hospitals. The benefits of such educational programmes are widely recognised, particularly where there a professional or applied orientation. Experiential learning can take many forms claims the author which can be either inside or outside the university. Sandwich degree courses are vocational and plan for experiential learning to be work-based. Nursing and engineering are such courses. Where learning takes place in a natural setting such as the workplace the experience is a stimulus for learning, claims the author. Furthermore, work related experience as a base for a degree course is acknowledged as important in building employment-related skills. Many courses now award credit in lieu of learning gained whilst on placements, outside the university, which forms part of a flexible educational system known as the Credit Accumulation and Transfer Scheme (CATS) and also Accreditation for Prior Experiential Learning (APEL). The challenge remains in bringing experiential learning within university programmes in order to enable learners to transfer their learning into future life and work, which has widespread professional applications requiring a combination of technical skills interweaved with knowledge, ethics and interpersonal skills. Experiential learning is therefore holistic states Beaty, (2003). What we learn from experience alone is not enough as learning needs to be situated and context dependent. Teachers therefore need to use examples, case studies and practical experiments, running alongside theoretical ideas in order to place them in context to make them relevant. If relevance is directly experienced by the students themselves, then learning is reinforced states Beaty, (2003). Another important point is that in order for experience to lead to learning, reflection is important as advocated by Kolb's model (Kolb, 1984, McLeod, 2017). This way, issues from experience are put in context by bringing to conscious attention. Experience is not enough on its own to support learning claims Beaty, (2003). Deliberate and conscious reflection is a requirement for experiential learning to take place, or as Beaty, (2003), puts it:

> *"If experience in the natural environment is to result in learning which promotes enquiry, critical thinking and understanding, the experience must be interrogated and reflected on in the light of theory"*

Various ways by which experiential learning can be integrated as part of a course are discussed by Beaty, (2003), which primarily take the form of structured and pre-planned practical work. In any experiential learning process, critical incidents (from experience) are linked to ideas and theories. Without the cycle of action and reflection, work-based, project-based and any practical learning remain sterile. The same can be said about academic courses which do nothing to link theory into practice through situated cognition. Purely class based and free of ABL (be it case-based or project-based), the course remains sterile. Of the examples given by Beaty, (2003), which constitute methods that promote experiential learning inside the university, and of especial relevance to engineering courses, the following are included:

- Laboratory experiments
- Simulations
- Case studies, including problem-based (PBL)
- Micro teaching
- Projects.

All of the listed rely on teacher-design experiences within a course in order to promote understanding of the relevance to the ‘real world’. Simulations have traditionally been incorporated within business programmes in HE and can be elaborate rule-governed and gamified which demonstrate complex relationships. Simulations can take many forms and as such may be easily integrated within engineering educational programmes.

Case studies have also, historically been popular and extensively used in vocational degrees. They can be real or imaginary, providing a rich learning experience, especially where teamwork is involved.

Projects are ideal in situations where scope for in depth learning is required and can provide very valuable experience of research, analysis and documenting (recording) as a means of honing report writing skills.

Action learning is based on the relationship between reflection and action claims Beaty, (2003). It often relies on focusing on issues and problems as a group, and taking a structured approach. It forms an important part of collaborative learning. Beaty, (2003) also discusses the merits of VLEs and how these can be good in helping to provide support of experiential learning.

The teacher's various roles in facilitating experiential learning are also discussed. The primary role of the educator is to provide a structure for a combined experience-learning facility through appropriate interventions. The role of the educator in supporting experiential learning changes somewhat from teacher to one of tutor, coach, trainer, mentor, supervisor or facilitator. The roles can often be combined as the teacher takes on multiple roles. In experiential learning, the term facilitator is often preferred to teacher, claims Beaty, (2003). This is because the role of the educator is one of support, in order that the learner gets the most out of the experience through provision of appropriate resources and intervention in support of the learning. Beaty, (2003), concludes that attention to supporting experiential learning within course design is crucial.

Borrego et al., (2008), reports on a three year experience in developing, facilitating and assessing Research in Engineering Education in the USA. Some of what they report represents the relationship between 'traditional' engineering research, education research, teaching and assessment. They report on exciting times to be part of the engineering education community due to paradigm shifting associated with engineering education as a result of reported ongoing research, although the shift is not as rapid as many researchers in this area would like. Discussions taking place in this area of research are often between engineering faculties and engineering education researchers and can be quite heated. The reasons for this are due to disagreements on methods, purpose and questions on engineering educational research. They report that despite many years of reform efforts, the necessary breakthroughs for new technologies, skills and educational methods have not come through, even though they are called for (Gabriele, 2005). A departure from past efforts is sought, in order to transform and not simply reform engineering education. Evidence of consensus is presented in that the research paradigm is gaining momentum and the identified cause of tension lies in inclusiveness and high standards of research quality, something that has to be disseminated to a wider engineering audience (engineering researchers, educators, faculty staff and engineering education researchers). The authors identify and define links between theory and practice in engineering and educational research as shown in figure 2.14.

	Basic Science	Linking Science	Application
Engineering Research →	→ Physics →	→ Mechanics →	→ Mechanical Engineering, Civil Engineering
Education Research →	→ Psychology (Learning Theories) →	→ Instructional Theory →	→ Instructional Design

Figure 2.14: Links between theory and practice in engineering and educational research Reproduced from (Borrego et al., 2008).

Borrego, (2007), describes the conceptual difficulties experienced by engineering faculty staff, as they become engineering education researchers. The reported findings were a result of funded rigorous research (by the USA National Sciences Foundation). The systematic analysis uncovered five main areas of difficulty:

1. Framing research questions with broad appeal
2. Grounding research in a theoretical framework
3. Fully considering operationalization and measurement of constructs
4. Appreciating qualitative or mixed-methods approaches
5. Pursuing interdisciplinary collaboration.

The research was guided by three questions:

1. What intellectual difficulties might be experienced by an engineering faculty member becoming a rigorous engineering education researcher?
2. What distinct stages or discrete processes are there to overcoming the difficulties?
3. What activities are likely to help engineering faculty staff overcome these difficulties, or avoid experiencing them altogether?

The author states that engineering education as a discipline in its own right is only just emerging and research in it is fundamentally different from engineering research.

Additional explicit steps to the research process are necessary for the engineers embarking in engineering educational work.

The scale up in engineering education research is reported by Jesiek et al., (2009), who report based on observational data from the 2007 International Conference on Research in Engineering Education (ICREE). They examine the question as to how engineering education is conceptualised as a discipline, community of practice and/or field. The authors confirm that through data gathered from delegates it is apparent that there is lack of clarity and continued ambiguity about the identity and status of engineering education research. Clarity on the goals and objectives of engineering education research is required in order to build the field's identity and supporting infrastructure whilst it is maturing as a research field. A number of research centres are dedicated to engineering education research such as the National Academy of Engineering (NAE) and National Science Foundation (NSF), both within the USA. In the UK and Europe there are the Royal Academy of Engineering (RAE), UNESCO's International Centre for Engineering Education (UICEE), The European Union's thematic network on Teaching and Research in Engineering in Europe (TREE) and the European Society for Engineering Education (SEFI). Their support is both symbolic as well as financial but it demonstrates that the domain now boasts an infrastructure comprised of funding and granting agencies, conferences and academic units. There has also been an emergence of several prestigious journals dedicated to research publications in the field:

- *Journal of Engineering Education (JEE)*
- *Advances in Engineering Education (AEE)*
- *European Journal of Engineering Education (EJEE)*
- *International Journal of Engineering Education (IJEE)*
- *International Journal of Mechanical Engineering Education (IJMEE).*

Although Jesiek et al., (2009), report on data from the ICREE conference, they also report on the ambiguity regarding the identity and goals of engineering education research address the following research question:

> *"What do engineering education researchers' discussions of identity, infrastructures, goals, and objectives tell us about the present state and*

probable future trajectory of engineering education research as a distinct domain of activity?"

They consider the ***discipline*** status of engineering education and how this is understood. There are cited variations in how the concept is used and understood (Borrego, 2007; Haghighi, 2005).

They consider the ***community of practice*** and its key elements such as the domain of knowledge and the stakeholders of that knowledge such as practitioners and society as a whole, action researchers of engineering education and shared practice.

They also consider the wide variations in defining the ***field*** of engineering education and how it is understood.

In the closing comments of this report, Jesiek et al., (2009), state that there is need for further reflection and analysis relating to:

- Goals and objectives of engineering education as a distinct domain of activity and the extent to which these should focus on research and/or practice.
- The most suitable configurations of infrastructure that will best support goals in engineering education.

In summary they argue that by engaging more directly with questions on goals and objectives of engineering education as a domain and research practice associated with it can improve the ability of stakeholders to assess the status of the field and also strategically develop in accordance to a future vision. Scaling up engineering education on a global basis introduces further challenges due to significant geographical and national variances in goals of engineering education. Such variance and disagreement in desired outcomes and competencies have been reported by Lucena et al., (2008).

(Downey and Lucena, 2007, Lucela et al., 2010), strongly claim that, that the success of engineering education as a discipline depends on more than just generating knowledge through research but also fulfilling external factors within the community, beyond the field itself. By this, they imply improvements in the engineering profession (by ethics as an example) and society more generally.

In acknowledgement of the expansion in engineering education research, Koro-Ljungberg and Douglas, (2008), have reviewed the state of qualitative research in the field by means of a meta-analysis of articles published between in 2005 and 2006 in the Journal of Engineering Education (JEE). The authors report that there has been a call for expanding the scope and rigor of engineering education research but specifically through qualitative methods in order to enable questions to be answered that qualitative method alone cannot answer. This type of research is becoming of increasing significance. As has already been identified (Levin, 2012, Heikkinen, 2012), well designed qualitative studies frequently build on epistemological consistency across grounded theories, research question and methods. A review of what has already been published as compared with these criteria is carried out by the authors in order to ascertain whether existing published work has prevalence of qualitative and methodical consistency in line with qualitative enquiry. They claim that very few qualitative articles have been published and even fewer have epistemological consistency. The article calls for changes in order that researchers expand their use of qualitative methods along with more careful attention to epistemological consistency. This is because, as is stated, qualitative research offers alternative ways of knowing and viewing the empirical world. Olds et al., (2005) emphasize that the research questions should drive the type of investigation (qualitative or quantitative). As an example, Donath's et al., (2005), uses qualitative methods to provide insight into ways student teams work, which would not have been possible by use of quantitative methods. Koro-Ljungberg and Douglas, 2008 argue that increased use of qualitative methods will increase awareness and understanding on the ways in which students learn in different settings, how teams interact and also how socio-political context shapes students' learning.

2.14 Review of games based learning articles

In this section the researcher reviews the work of several authors who have published work on gamification in education and particularly in engineering education applications. As there is a vast amount of published work in this area I shall focus specifically on engineering applications to date, execution and measurable benefits as these are of specific interest and relevance to own research.

The work of Katrin Becker (Becker, 2007) has received international recognition particularly in digital games based learning. Becker has uncovered the instructional design principles in existing successful games by ‘reverse engineering’ them. The focus of Becker, (2017) is on digital games as are most of publications on gamification for educational purposes. Even though the educational frameworks may be present, the difficulty lies in persuading teachers to embrace digital games which are highly technology dependant. To achieve this, they first have to be made aware of their potential as well as limitations. Much of the value in Becker’s work lies in the defined instructional strategy. The widespread acceptance of such games as a medium for learning will always depend upon a large extent on the abilities of new and practicing teachers to take full advantage of the medium. In a study (Becker and Jacobsen, 2005), it was revealed that approximately half of teachers surveyed have an interest in trying games but this largely depends on how the word is interpreted. If a game is redefined as an interactive simulation, then the interest is much wider. This is because the word ‘game’ has connotations of digital arcade or computer type games for fun. There are therefore genuine barriers to their adoption and much suspicion especially as they anticipate that there would be even greater demand on their time to learn new and unfamiliar technology in order to implement such games.

Although there is a growing body of knowledge on DGBL, much of the published work has been written by academic scholars, is of a research nature, and their work is not read by practicing teachers who have more immediate concerns in planning their next lesson. Becker, (2007), therefore recognises that published academic work is not read by teachers because of time constraints, synthesizing findings from publications and then create lesson plans from scratch using what is too often unfamiliar technology. Resources are therefore required, that are readily available. The key here, in my opinion, is identifying frameworks which incorporate gamification within the classroom by using existing resources that the educator is already familiar with. The only condition that is necessary for this is that the educational framework is present such that I am able to identify the pedagogical benefits. There has been a body of research on educational games (Kirriemuir and McFarlane, 2004) confirming that there is potential offer for inquiry based, constructivist approach that allows learners to engage with material in an authentic and safe environment. However, as pointed out earlier on the discussion on Assessment for Learning, ‘instructional technology only works for some kids, with some topics, and under some conditions—but that is true for all pedagogy. There is nothing that works for every purpose, for every learner and all the time’ (Mann, 2001).

Markopoulos et al., (2015), focus their publication on gamification in engineering education and professional training. They report that in academia, gamification remains in its infancy so viewed upon as novel. This may be the case in engineering but not particularly the case in other educational sectors such as business, in which business and production simulation games have been about for many years. There is however a distinct lack of empirical evidence of the pedagogical benefits of such games, as is confirmed by the authors. Their critical comments are based on the lack of empirical studies. The authors refer to gamification in an educational environment as the process of converting what would usually be viewed as a tedious task in to an engaging activity with the desire to incorporate education outputs. In my opinion, the latter should be mandatory. Although not demonstrated by example, the authors also state that gamification can encompass what is already present such as a website, a VLE, an online community etc. In other words, they propose that gamification is a strategy that utilises existing resources. The importance of gamification in STEM subjects is emphasized in a study in the *New York Times* that is referenced by Markopoulos et al., which highlights the large number of undergraduates that drop-out or transfer from undergraduate studies in STEM studies in order to transfer to non-STEM subjects. In the article it is reported that approximately 60% of undergraduates drop-out or switch. If this can be reduced through the incorporation of gamification within STEM subjects’ curriculum, then we have accomplished something worthwhile. Such drop-out rates in STEM subjects are of great concern to governments and business leaders of industrialised and economically strong nations (such as the USA and UK) as they rely on a strong supply of such STEM graduates.

A comprehensive research survey (Hamari et al., 2014) in which well-known databases were searched for scientific work using the key terms like gamification, gamef*, had exposed 7500 results. Once these were filtered down to relevant, unique, peer-reviewed and based on empirical research, only 24 remained. These were mostly papers published in computer science conferences and only a few relate to learning gamification. A similar literature survey was conducted by Seaborn and Fels, (2015), which searched specifically for gamification in various subject areas. The search resulted in 769 works which was reduced to 31 once processed which largely consisted of conference publications. This can be attributed to the fact that relatively new topics tend to first appear as conference proceedings before they start appearing in scientific journals. The researcher found this to be the case as part of own research. The results of both surveys (Hamari et al., 2014 and Seaborn and Fels, 2015) are graphically presented in figure 2.15.

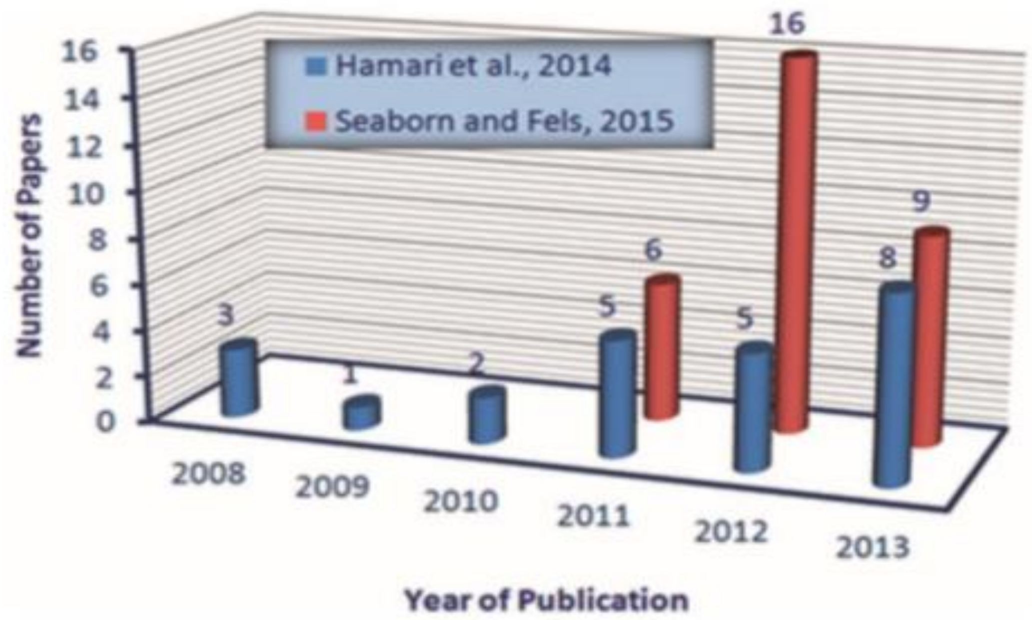


Figure 2.15: Literature survey on gamification by Hamari et al., (2014) and Seaborn and Fels, (2015). Reproduced from (Markopoulos, 2015)

The authors identify various types of games of which puzzle, adventure, simulation, strategy type are included. With regard to gamification in the classroom the authors recognise that it is not always necessary to create a special purpose game or purchase special COTS games as adaptation and creativity will often suffice in creating a situated learning gaming environment, something that the researcher supports in this research. Such an opinion pertains to the participation of learning activities that include elements from games. Such elements are progress mechanics and can include earning points, overcoming challenges or receiving prizes for accomplishments, following a narrative, receiving feedback, offering opportunity for problem solving and much more. When some of these elements are introduced into the classroom, it can be characterized as gamified.

Although a number COTS games are identified by the authors with potential application in STEM subjects (such as Bridge Builder and Fluidity which are puzzle games used in applications such as physics or structural integrity), they also make reference to virtual environment type games which are built within CAD-type environments. An example of such a game would be a factory simulation game in which participants attempt to optimise layout of facilities in order to achieve the shortest throughput time from production start to finish by avoiding bottlenecks. Parameters can change during participation such that the gamer is required to respond to changes (such as a surge in production). Such games have traditionally been available for assisting in the training of students in operations management. Markopoulos et al., (2015) conclude that gamification has a positive effect on engineering education by assisting in the learning of difficult subjects, increasing learner motivation, scientific knowledge, collaboration and interest.

Fengfeng, (2008), reports on a case study in which the use of educational computer games have been applied in a summer maths educational programme in order to facilitate higher cognitive achievement and metacognitive awareness of senior secondary level pupils. A more positive attitude towards learning maths was also reported, as this was hoped for. The case study served as good guide in that it revealed that not every game would engage pupils but highlighted the value of situated learning activities within gamification, making games challenging whilst also pleasurable, scaffolding reflections and also helping in designing activities away from the computer.

Based on several cited articles holding arguments in favour of computer games in education, the following key benefits are identified:

a) Computer games can invoke intense engagement in learners

b) Computer games can encourage active learning or learning by doing

c) Empirical evidence exists that games can be effective tools for enhancing learning and understanding of complex subject matter (Ricci, Salas & Cannon-Bowers, 1996)

d) Computer games can foster collaboration amongst learners (Kaptelin and Cole, 2002).

Despite the published articles, there are still many sceptics and this is because of a lack an empirical-grounded framework for integrating games within the classroom.

The study by Fengfeng, (2008), brings to light several important points. As claimed by Rieber, (1996) and Okan, (2003), designing and using computer games for learners is more than just a form of sweetener for education and Fengfeng, (2008) has evidenced that it is only by careful design with imagination and creativity that learning support features, and game-based pedagogy, that can enable deep learning (itself being part of engagement). There are limitations in Fengfeng's case study that are emphasized and these are that the experimental group consisted of secondary school pupils from a specific small sample group, diverse in gender, socio-economic status, prior maths abilities. Yet, the school had historically achieved higher levels of proficiency as compared to other schools of similar demographics.

Arango et al., (2008), reviews several applications of commercially available computer game engines with potential for implementing virtual education and training environments. The potential application reviewed vary widely and include health and safety training, medical training such as for surgeons, rehabilitation environments for war veterans, chemistry training (within virtual laboratories) and biology training (using virtual dissection). One of the Mechanical Engineering case examples is based on a standard platform and developed to enable students to virtually assemble an experimental apparatus to demonstrate concepts of gears, belts, inertia of machine elements, all within a game-based virtual laboratory environment and subsequently carry out experimental procedures by means of an industrial emulator system. This potentially can offer immense learning potential in a virtual environment but is a very specific bespoke development based on an existing engine platform (a development at Stevens Institute of Technology), see

http://wiki.garrysmod.com/wiki/?title=Land_Vehicles

Such simulation systems allow for the performance of virtual experiments using software implementations (Chang et al., 2007, Aziz et al., 2007). The great benefit of being able to combine a games-based environment with remote and virtual experiments is that learners are able to repeat procedures or experiments more than once, at their own time. It is reported by Arango et al., (2008), that engineering students indicated improved knowledge of concepts which were also covered in class lectures (through reinforcement of knowledge) and has expressed satisfaction with the laboratory approach. Such simulation scenarios align with instruction theory of learning by doing (Activity Based Learning) and provide opportunity for higher level learning in cases where error-prone, expensive or complicated tasks are involved.

Ariffin et al. (2013), set out their programme of research with an aim to establish the effectiveness of GBL in Higher Education. They propose a research framework which is based on gathering a large quantity of data from learners of varied backgrounds in order to establish their motivation for learning based on ethnicity, culture and native language. Therefore, although the research does not refer to a specific GBL application it undertakes a statistical analysis to determine which factor influence a learner's attitude hence motivation to learn from GBL. The research was based in Malaysia and only considers the subsets of Malaysian cultural and ethnic group, which differs from the multi-cultural group of students that this research is engaged in. It draws some interesting conclusions but importantly it undertakes a good review of previous work and in doing so identifies shortcomings in GBL research. The authors confirm the shortage of empirical evidence on its effectiveness in support for training and learning as do many other authors (including Sotomayor and Proctor, 2009). Most claims are based on teacher's judgement or anecdotal evidence with unsubstantiated evidence on effectiveness of games as learning tools. An evaluation framework is therefore said to be required. The effect of learner's background and game design influence as well as motivation for overall performance was reported by Osman & Aini, (2012).

There are therefore two research questions that the authors (Arrifin et al., 2013) address which are:

1. Whether the learner's ethnic, cultural and language background have a correlation with learner motivation to learn as well as performance.
2. Whether a GBL environment has a correlation with learner motivation and learner performance.

The definition of GBL is taken to be as defined by Hays, (2005) and Freitas & Oliver, (2006) which considers GBL to have been specifically designed or modified to meet learning objectives.

The results from the numerous questionnaires that were analysed by the authors were hypothetical, as there was no case example in place. The results obtained revealed that learners had indicated that their willingness to embrace GBL was largely based on their background. This had validated the authors' proposed framework and the future work is to develop games that integrate with learner background parameters of culture, ethnicity and native language. It is of the opinion of the researcher that the conclusions drawn from this research, though may hold some truth, they are too general in that variance in GBL design and approach can greatly vary as has been evident in the review so far.

Ariffin et al., (2013) look at the definition of GBL and define it as 'a physical or mental contest that has specific rules, with the aim to amuse and reward the gamers'. It is 'an artificially constructed, competitive activity with a specific goal, a set of rules and constraints that is located in a specific context'. Although a game does not represent reality, it is a constructed activity that resembles portions of reality. Games are interactive, which promotes particular behaviours like individual control, trial- and-error and constant change (Birnbaum, 1982). Games provide situated experiences in which players are immersed in complex problem solving tasks (Squire et al., 2005). The authors have identified the type of games that capture researchers' interest as being the instructional games. These have been defined by Hays, (2005) and Freitas & Oliver, (2006) as being instructional that are designed or modified to meet learning objectives. Such 'serious games' meet their objectives by including rules, constraints and activities that closely replicate the constraints of the real world tasks that are being trained. Hays, (2007) classifies serious games by the type of task to be trained (skills and procedures learning games, action games, role-playing games and strategy games). Ariffin et al. (2013) have drawn several interesting points from their review of previous work in GBL. They have identified that despite there being wide use of games in training and learning, there remains a lack of empirical studies that assess their effectiveness for learning and training. The work of Dorn (1989), Sotomayor & Proctor (2009) and Conrad (2010) verifies that there is insufficient research that looks into the effectiveness of GBL. Most work in this area is based on the teacher's judgement and anecdotal and personal encounters. Many researchers have proven that using games increase motivation and interest and makes learning fun, there is still missing evidence on the effectiveness of games as learning tools. This is also supported by, Hainey, Conolly & Boyle (2009) who suggest that there is a need to create an evaluation framework for evaluating serious games that are used for learning purposes. Most researches have failed to identify or include control groups that would allow comparison of the results between groups (Hays, 2005). Hainey, Conolly & Boyle (2009) also claim that the existing GBL framework is lacking in pedagogy aspects. According to Ariffin, (2013), there are 16 evaluating frameworks on games and none of them concentrates on learner background, particularly on culture, ethnicity and language spoken by the learners.

Chen, (2014) explores students' behaviour during a competition-driven educational game, known as Pet-Master. There are few studies that have addressed this aspect of GBL, according to the author. However, the entire study is based on one game. It carries out empirical analysis to determine how behaviours can be categorised in to competition-driven and learning-driven cycles, claiming that participants frequently switch from one mode to the other during participation. The results are used as a basis for developing a design framework for competition-driven educational games, which reveal the relationships between social, learning and gameplay dimensions. The framework may aid in optimising learning outcomes of games developed in future as well as maximise educational benefits. It is emphasized that GBL is used to increase students' interest and motivation leading to a more enjoyable learning experience and deepened perception. The choice of game on which this article is based, Pet-Master, does not appear to have any practical significance with engineering applications, however, the conflicting behaviour of participants (from competitive to learning) is an aspect of interest.

The effects of the Gamified class are explored by Kim, (2013). Although the author is critical of past work in gamification in engineering learning environments as lacking in quantitative analysis, the discussion of the paper is centred on the response of twenty-eight engineering undergraduates in a Korean University following a gamified class activity. Kim, (2013) analyses the response from the questionnaires which serve little more than to reflect the students' perceptions and impressions of gamification after the event. This is hardly qualitative analysis as no evidence of learning improvements is presented. Improved motivational aspects are expressed by learners. Kim, (2013), bases his game design, which isn't described in any way, on previous research that produced an interaction matrix of desirables for game mechanics. These include points levels, challenge levels, virtual goods, leader boards and gifting. Kim, (2013), analyses questionnaires in order to conclude that the gamified class proved to be more effective than traditional delivery, in motivating students. Based on students' response to a particular question Kim, (2013), states that learning was less stressful through gamification than through traditional delivery. Reference is made to Maslow's Hierarchy of needs by Kim, (2013), who relates to gaming activities as satisfying needs placed at levels 3 and 4 within Maslow's hierarchy (belongingness, group working, relationships, self-esteem, achievement, mastery, independence, status, prestige). See figure 2.16 for Maslow's Hierarchy of needs. In conclusion, Kim, (2013), identifies gamification as a "new tool for effective motivation of learning desire" and proclaims that lecturers should have little or no concern on lowering the quality of delivery. However, I believe that the small sample group used could not have provided accurate data and no measurable improvements in meeting learning outcomes were reported.

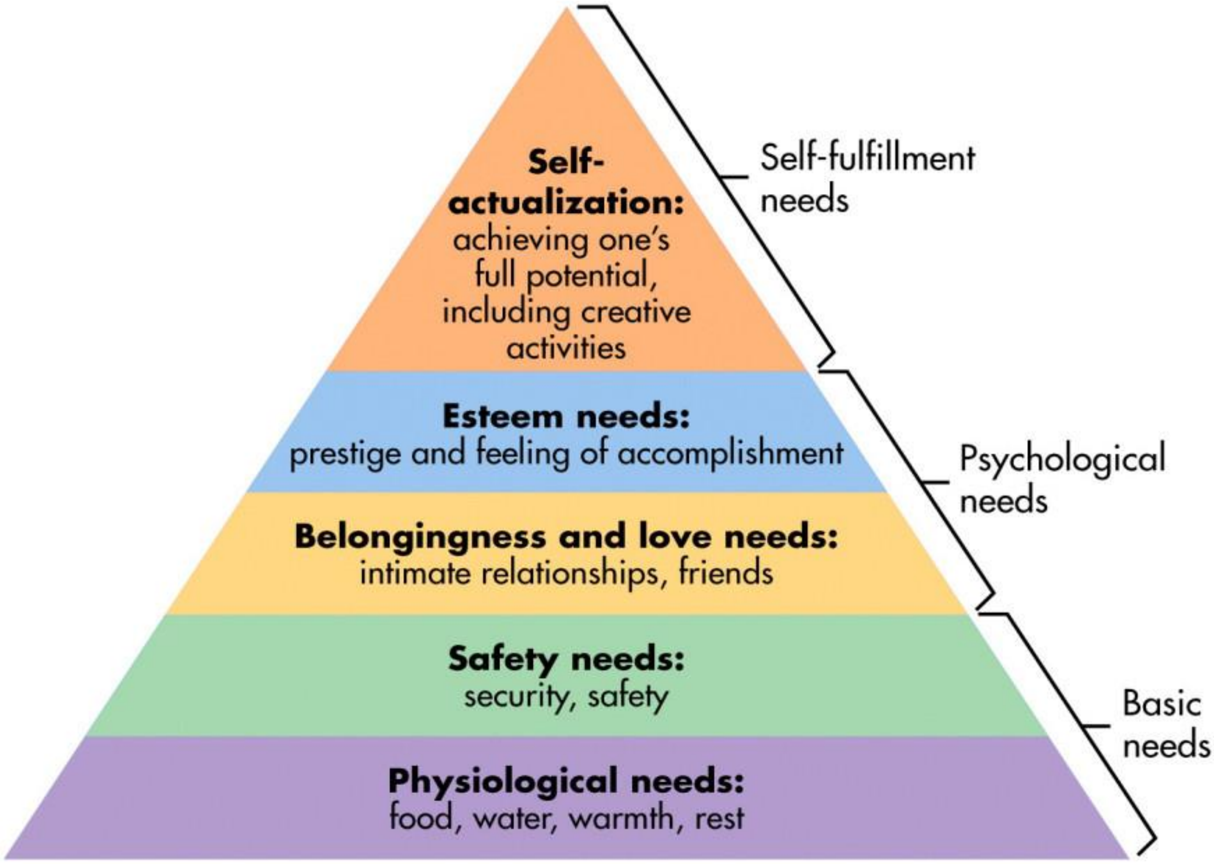


Figure 2.16: Maslow's model of human hierarchical needs. According to Kim, 2013, gamification for learning satisfies the human psychological needs, levels 3 and 4 in the hierarchy. Reproduced from https://www.simplypsychology.org/maslow.html [Accessed 25/2/2019]

Good GBL design should create a skilful interplay between gaming and learning is claimed by Gunter, Kenny, & Vick, (2008). This is in light of a surge of what are claimed to be educational games but with poor educational content added in an ad hoc manner. Simply by housing some educational content into a game in order that the player/learner is motivated does not necessarily make an educational game claim Gunter et al., (2008). Any game needs to be based on sound and well-established instructional theories otherwise there is a high risk that the game will fail in meeting its educational objectives. If academic learning is to take place, the authors profess that a new design paradigm must be developed. This forms the basis of their article, in which they describe RETAIN (Relevance Embedding Translation Adaptation Immersion & Naturalization) which is a design and evaluation model for educational games. It is developed with reference to established taxonomies and uses a rubric based on a matrix in which they allocate weightings to various attributes in order of most to least desirable for games. The RETAIN model is used as means for benchmarking games in order to evaluate them for educational effectiveness, based on the rubric. Two COTS games are identified as being educationally effective and noted as being exemplars. The first is commercially known as *‘Maths Blaster’* and the other is *‘Where in the World is Carmen Sandiego?’* Both these games are used at secondary level and whilst ‘Maths Blaster’ focuses solely on improving skills in maths, ‘Where in the World is Carmen Sandiego?’ is intended to teach geography. The former games have sold in quantities of millions and the latter has been successfully adapted for the classroom. The authors emphasize that their review is not an endorsement for these two games but purely a review with intent to demonstrate the potential of the rubric in helping educators make decisions on the effectiveness of games to be used in the classroom. This is where interest lays, hence reason for reviewing it.

Although many games offer compelling context via interactive, engaging and immersive activities, hence their widely emerging popularity in the classroom, few actually are backed with sound empirical evidence for being of benefit, educationally, if used on a standalone basis. This statement is backed by most research on the subject of effectiveness of learning games. According to O’Neil et al., (2005), as with any other effective mediated intervention, its success depends on the extent in which it forms part of instructional best practices and supplemented with additional educational curricula. Gunter et al., (2008), also make reference and acknowledge the value of Prensky’s contribution to field of GBL but especially to DGBL (Prensky, 2003). Prensky has published in many popular journals in which he has listed many attributes of the ‘net generation’ and how they learn in lieu of their digital literacy and how they possess a unique set of cognitive characteristics. Below, are Prensky’s most popular listed attributes, with translation of each in parenthesis, indicating deficiencies.

> “• A preference for graphics over text and a corresponding increased ability to recognize patterns (i.e., they are text-averse)
> • A random and informal approach to information (i.e., linear learning is anathema to them)

• The need to stay connected with their peers and actively participate in the learning process (learning is completely a social activity)
• The need for an immediate payoff (i.e., instant gratification—depth of processing is lacking; making topical relevance more complicated)
• A view towards information as a commodity (i.e., the traditional view of knowledge as an asset that one acquires and retains has been replaced with the idea that it is a consumable item that is retrieved and utilized 'just in time' and is then disposed of until it is needed again)".

The list of attributes indicates how today's young learners acquire knowledge both inside and outside of the classroom.

The RETAIN model for evaluating GBL was derived by Gunter et al., in consideration of other educational models such as Gagné's nine events of instruction (Gagné, 1985) that serve as a guide for developing and delivering instruction (commonly known as Gagné's instructional theory). Although Gagné's instructional theory is traditionally used in reference to lessons, the events can also be used in reference to a whole curriculum. Another framework used as a guide for the RETAIN model was Keller's ARCS (Attention, Relevance, Confidence, Satisfaction) model (Keller and Kopp, 1987). Table 2.7 lists Gagné's nine events alongside Keller's ARCS model in order to identify common game design elements.

Table 2.7: Comparing Gagné's Events of Instruction, Keller's ARCS model, and common game design elements. Reproduced from (Gunter et al., 2008).

Gagné's Nine Events	Keller's ARCS model	Common game elements
Gain attention	Attention	Scenario exposition
Inform of objectives		Problem setup
Stimulate recall	Relevance	No existing game equivalent
Present stimulus/lesson		Offer challenge/choice
Provide learner guidance	Confidence/challenge	Provide direction
Elicit performance		Elicit action/decision
Provide feedback	Satisfaction	Discernible outcome
Assess performance		Success/failure screens
Accommodate retention and transfer		No existing game equivalent

Gunter, et al., (2008), draw some valuable conclusions from their research in good game design strategy. Most importantly is that they should share good instructional strategy and educational theory and share a number of important features (such as being fun and motivating). Ultimately, as well as being of educational benefit, they must offer optimal challenge, have appropriate and unambiguous outcome goals, provide clear, constructive, and encouraging feedback, and offer elements of curiosity. They should comply with educational taxonomies such as stimulating recall from previous lessons whilst transferring previously gained knowledge to a new situation, encouraging higher order thinking. A serious game goes beyond just incorporating educational content within an engaging atmosphere. Thought and planning is required in order to intertwine content at each stage with game play, providing feedback and hints.

In Law, (2019), a Game-based Action Learning (GAL) (or Game Action Learning) case is presented in which, mostly post-graduate engineering students, combined with other disciplines partake in an activity which is intended to educate learners in Project Management (PM) techniques. The approach is very pragmatic and although it displays certain GBL traits, the delivery framework is more apt to Project-action Learning (PAL) (Law, 2004). The key research question in Law's article is whether Game-based Action Learning is an effective approach in Project Management (PM) education. There are attributes required for effective PM education, for which, a purely theoretical delivery (such as the construction of project network diagrams and the use of a software tool for determining earliest start and latest finishing times of events) is inadequate and inappropriate. A more pragmatic approach is required in which learners become familiar with the tasks associated with a complete project (i.e. a construction site) and the practical obstacles that occur in practice. As is often the case in engineering education, a gap between theory and practical knowledge needs to be filled. Law's case example attempts to close the gap by studying the effect of a combined approach of both action learning and game-based learning. Both AL and GBL are effective in enhancing students' participation and motivation. The contribution to knowledge is the applicability to PM. The learners consist of both full-time and part-time students, this being a bonus, due to practical experience of part-time students (who are industry sponsored) sharing their practical experiences. The activity was run over two full weekends (4 days in total) and the brief was to work on a team project to develop a new product, specifically, a paper flying object for a sole client from beginning to point of sale (delivery). Law reports improved assessment results with observations made of certain shortcomings including more careful consideration to team-grouping guidelines (Belbin, 1981).

This paper discusses the use of Serious Games (SG) for supporting development of entrepreneurial mind set in undergraduates of technical universities. It illustrates how the use of games can help students develop basic concepts of entrepreneurship and company management. The authors have addressed the need for a range of commercially available games with the most appropriate mix for their use in courses by keeping into account targeted competences and skills, use ability and pedagogical effectiveness. The authors claim that from a methodological perspective, SG can foster learning as they offer students a genuine 'situated' learning experience (Van Eck, 2006) and support the ‘learning by doing’ approach. According to the Dale’s cone of experience, students can remember 10% of what they read but almost 90%, if they engage in the job, even via a simulation game (Dale, 1969). De Grove et al., (2010) stress that games should be considered as

> ‘de facto effective learning environments because games challenge and support players to approach, explore and overcome problems’

Games are also claimed to provide immediate feedback which is efficient for procedural learning and assessment (Bellotti et al., 2010) and lend themselves to collaborative and social use (Romero et al., 2012) and can be used for lifelong learning. The authors claim that games can show relevance and application of topics and skills that may be difficult to explain in words.

2.15 Key points to draw from literature review

The review had commenced by looking at Bloom’s Taxonomy and the later revised Taxonomy by Anderson in identifying learning domains. The educational frameworks of Dewey (based on pragmatism) and Gagné (based on theory of instruction) were considered along with Piaget’s and Bruner’s theory of constructivism and reflection. The work of Lave and Wenger (1990) on situated and social learning theory, underpinned by the work of Vygotsky was also reviewed. Combined, the theoretical frameworks of such past cited researchers has directed this research towards a hybrid framework for application to engineering education with its requirements for unique sets of skills and knowledge.

The literature review has identified some key gaps which lead as to key research questions. The distinction has arisen in the following:

There is a distinct lack of empirical data on the pedagogical benefits of educational games despite the large volume of publications that exist on gamification (Markopoulos et al., 2015). Additionally, there is also a lack of Games Based Learning activities specifically within engineering education, which have been reported (Seaborn and Fels, 2015, Hainey, Conolly & Boyle, 2009, Kim, 2013).

A stronger research agenda is required to be driven by theoretical and empirical research (Haghighi, 2005).

There are gaps in undergraduate engineering education which can be closed through Action Research (Jensen, 2015) and AR remains rare in engineering education research (Case and Light, 2011).

There are several missing topics in engineering education research with a recognised shortfall of work in these areas. These include gaps in knowledge in topics such as motivation, teamwork and collaboration (Johri and Olds, 2014).

There is insufficient knowledge generated that can be used by engineering education practitioners (Johri and Olds, 2014).

There is a lack of conversion between conference published work into more prestigious journal articles (Johri and Olds, 2014).

The work of Russell, (2008), amongst other, report positively on the use of EVS systems within the classroom but we have not identified work that reports on causation between its use and changes in assessed results.

Similarly, although much has been reported on DGBL and its benefits as suited the younger learners (Prensky, 2003), GBL and especially DGBL remains an unknown quantity in terms of its benefits, especially in engineering education.

I have considered the extensive meta-analysis of Freeman et al., (2014) that reports on considerable marked improvements in assessments as a consequence of active learning. This claim is scrutinised by Streveler and Muhsin (2017) for not being a universal solution. We propose to test the robustness of this by applying it in mechanical engineering subjects.

I have identified the core methodology and considered the work of Levin, (2012) who identifies five factors that support high rigor in the writing of scientific (research partnering; controlling biases; applying standardised methods; exploring alternative explanations and trustworthiness in reporting results). Credible AR would result in integrity should we abide by the five factors of rigor.

I have considered and able to draw from the documented cases of Active Learning examples published by researchers such as Mioduser and Betzer, (2007), Perrenet et al., (2000), Horgan, (2003), Bligh, (2002), Overton, (2003), Beaty, (2003), amongst other, in order to blend different techniques and apply them within own Active Learning cases with interventions.

It has been encouraging to the review the work of Borrego t al., (2008) who report with considerable persuasion and authority on the prominence of exciting times within the engineering education community. A paradigm shift associated with engineering education is overdue (Gabriele, 2005).

The urgent call for expansion, scope and rigor in engineering education research has been identified through review of work by Koro-Ljungberg and Douglas, (2008), Levin, (2012), Heikkinen, (2012) and Olds et., (2005)

2.16 Summary

Chapter 2 consists the main body of the literature review and due to many facets associated with engineering education research, it categorises the review in to several areas including flipped learning, educational action research, gamification and active learning. The common theme is engineering education research. Review of previous work is also included as part of case study chapters as it is more specifically relevant to those case studies. This chapter is key in identifying gaps in knowledge, posing research questions and identifying potential novel aspects all of which are presented in chapter 3. Chapter 2 has indicated the lack of quantitative research in engineering education. Although there have been a range of approaches to researching Active Learning, very little of it quantifies the benefits associated with Engineering and Technology subjects (Freeman et al., 2014). Within the realm of active learning, the literature review also explores GBL in Higher Education. Although widely applied, its benefits remain vague due to unquantified results. This is especially the case in its relatively new application in Engineering and Technology where much further scope exists (Markopoulos et al., 2015). The guidelines provided by Becker (2005b) offer a solid foundation for the potential creation of new novel games in the subject area of mechanical engineering and technology subjects. Published work on e-Learning is bias towards an 'all or nothing' approach to e-Learning interventions (Salmon, 2010). Following the review, I ascertain that e-Learning offers a valuable enhancement to learners if interweaved with more traditional practices, especially in subject areas of engineering and technology. The limited amount of Action Research by engineering education practitioners has also been brought to light in the literature review which leads me to adopting an AR approach to my thesis. Kemmis et al., (2014b, p.4) describe AR as “a practice-changing practice”. This study aims to change HE-based engineering educators’ practice.

Chapter 3 – Research Methodology

This chapter outlines the study's research methodology and the procedure for each of the research case studies.

It identifies frameworks for new practice and gaps in knowledge based on an extensive literature review of published work in this research field. Also, it poses some key research questions leading to the novel contribution to the field of engineering education.

3.1. Introduction

In order to justify the design and method of this research cases studies the researcher poses theoretical arguments. Many of these arguments are based on experience from practice. However, in order to either prove or disprove them, I refer to certain methodologies. Dealing with methodologies is an important part of research because it governs the quality and scope of the research in order to allow it to develop. It has become apparent from review of previous work in chapter 2 that in research I must be explicit about the methodological decisions I make and how I use these decisions to represent the work. I must be aware of the methodologies available to us for consideration and in engineering education there are several. Some of these, such Action Research, are well establish in social sciences and are finding a place in engineering educational research. There are other 'emerging' methodologies in engineering education research which will help to find answers to the research questions. However, engineering education research is a relative new field; therefore specific case examples are limited.

By broader definition, as a first part to this chapter I wish to present the theoretical justification for the methods used in case studies, applied methodology.

3.2. What are the gaps in knowledge identified by the literature review and addressed by this research?

Section 2.16 summarises chapter 2 and identifies the gaps in knowledge. The most prominent of these include lack of quantifiable results in Active Learning, especially in engineering and technology subjects. Games based learning forms one part of this. There are many other facets to Active Learning where interventions such as flipped learning and e-learning interventions to enhance teaching and learning, fall short of being extensively explored.

The creative application of interventions for enhanced Teaching and Learning in Engineering and Technology subjects, combining techniques such as active learning, e-Learning and Gamification and evaluation of these.

Development of hybrid teaching strategies which are based on existing frameworks and theories (such as Laurillard's and Kobl's) but with specific application to Engineering and Technology subjects and evaluation of these.

There is evidence of distinct lack of empirical data of the pedagogical benefits of educational games despite the large volume of publications that exist on gamification (Markopoulos et al., 2015).

3.3. What are the key research questions?

The literature review has considered existing and ongoing research in which the researcher holds an interest due to significance to own work. It has also assisted in identifying gaps and formulating the key research questions. These research questions are contained in this section and are also addressed fully in the presented case studies that form the main body of this thesis and concluding chapters.

- To what extent does the use of Electronic Voting Systems (EVS) result in improved student learning within a Mechanical Design undergraduate degree at a Post-1992 university?
- What are students' perceptions of the use of Electronic Voting Systems (EVSs) within their Mechanical Design undergraduate degree at a Post-1992 university?
- To what extent does the use of a Flipped Classroom result in improved examination results for students on an Engineering undergraduate degree at a Post-1992 university?
- Are learners able to achieve improved examination results in subjects delivered by a revised method of the Flipped Classroom and can they subsequently achieve a higher level of learning?
- What are students' perceptions of the use of the flipped classroom approach compared to conventional classroom-based teaching within a Mechanical Engineering undergraduate degree at a Post-1992 university?
- To what extent is Action Based Learning (ABL) a suitable teaching method for students on an Engineering undergraduate degree at a Post-1992 university?
- How effective is GBL as a teaching, learning, and assessment strategy for undergraduate Mechanical Engineering subjects?
- How does Blended learning compare with other teaching strategies for undergraduate Mechanical Engineering subjects?

These research questions were composed at the start of this research and designed to question the possible improvement in effectiveness of teaching and learning for delivering engineering and technology subjects through varied and blended teaching and e-learning techniques. An indication of success would be an outcome that would encourage students to learn by greater involvement (partly through asynchronous self-directed learning), stimulation and inquisitiveness.

- It is anticipated that this research would widen but retain specific aims leading to quantifiable novel aspects in teaching and learning within the subject area of CAD/CAM and closely associated subjects. This would confirm that no single technique works to best effect with a group of learners, therefore a blend of techniques would be considered in accordance to the learners' knowledge and abilities, desired learning outcomes and nature of the subject delivered.
- From the outset the researcher embarked on a path to consider a number of issues which would allow us to utilise a framework for the analysis of effectiveness of current teaching and learning practices in the mechanical engineering subject area and to develop suitable interventions to improve teaching and learning effectiveness.

Following the literature review, the research questions remain open, as to whether such interventions will improve subject delivery effectiveness on a micro level but also a macro level.

3.4. Methodology

From the literature review it is evident by the volume of supporting articles that conventional delivery in engineering and technology subjects often lacks integration between theory and practice. It therefore falls short of industry skills requirements. I seek to apply practical or industry focussed teaching and learning methodology (Ziming, 2008) and assess the effects of this through several research questions. (Cousin, 2009) states the following in an attempt to briefly explain methodology:

“Crudely, methods are best understood as the tools and procedures we use for our

inquiries and methodology is about the framework within which they sit.”

(Cousin, 2009, p. 6)

The core methodology selected for this investigation is action research (AR) and this is due to the nature of the work being practice and practitioner based. AR is the methodology of choice as it is a critical educational research methodology. It is traditionally applied in social situations in order to foster change within an everyday natural context (rather than within removed and simulated settings) and almost always determined and conducted by the active engagement of the practitioner for continuous improvement. In *Technical AR* we (the practitioners) facilitate the process and judge the changes. In *Practical AR* the participants (the learners in the covered cases), participate more fully and reflectively in the research process. The researcher is applying both these methodologies.

Although there are various other definitions of AR the latter is the clearest definition encountered.

In short and in accordance to Kember, (2000), it must be ***reflective***, ***systematic*** and ***cyclical***. AR allows us the flexibility to make changes in accordance to experience and circumstances and is subject to critical and rational judgement.

Kemmis and McTaggart, (1988), describe the implementation of AR as continuous cycle in which we:

- Plan an action in order to improve what is already happening
- Devise an action plan
- Observe the effects as a basis for further planning and subsequent action etc. for a succession of cycles.

(Jensen, 2015) addresses gaps in undergraduate engineering education through AR. Their application was in sustainability and leadership subjects and referred as “mixed method action research philosophies”

We are informed that AR is still relatively rare in engineering education research (Case and Light, 2011)

In chapter 2 it was noted that AR has various definitions in order to avoid confinement whilst also offering a research methodology for wider participation (Altrichter et al., 2002). There can be several alternative approaches. For definition, a sensible mix of pragmatic and flexible are advocated. AR advocates a consistent approach with flexibility, pragmatism and collective response to problem solving.

AR in education is not new and has been demonstrated in several studies. In chapter 2, a case was cited in which gaps in engineering education were identified (Jensen, 2015) through AR.

In the methodology I seek to achieve the following:

1. Present questions that I am are able to investigate by empirical means
2. Link the research to relevant theory which has been considered in chapters 1 and 2
3. Our method should permit us to investigate the research questions
4. We aim to explicitly provide a coherent chain of reasoning
5. Replicate the methodology across more than one case study, and/or re-apply to the same case study
6. Disclose the research findings in an open and honest manner (in compliance with AR ethics) and encourage professional scrutiny and critique.

The instruments of the action-based case studies are designed, implemented and evaluated to facilitate addressing the research questions of this study whilst also achieving the other listed points of methodology requirements.

Although AR has been considered as the core methodology, I also recognise the importance of using it in conjunction with other methodologies in order that I do not lose sight of theoretical perspectives and epistemology. This is supported by Cousin, (2009), who stated, with reference to the growing field of engineering education research, that it is *“a big playground where no one methodology needs to hog the best swing”*.

I assert that I am using an action research methodology and that within each of my case studies are examples of teaching interventions.

With deliberation to other methodologies and reference to my research questions, in addition to AR, it emerges that other methodologies become apparent in the case studies (be it to a limited extent), which are:

- **Case study**
- **Grounded theory**
- **Ethnography**
- **Phenomenography**

3.4.1. Case study methodology

A case study can include one of several examples from a major in-depth study or examination of smaller in-class phenomena. Depending on the research question, a methodology can be used as a motive for validating findings in a single case or comparing of results between cases. Case study methodology can be appropriate for addressing a research question(s) with specific application to a new innovation or initiative to enhance teaching and learning.

There are several ways in which a case study can be employed to gather data in research including informal observation, surveys from learners, interviews with individual or groups, feedback from staff and assessment results.

3.4.2. Grounded theory methodology

This is a well-established methodology for supporting qualitative data in social research. It is a general methodology used by gathering data in order to establish a theory. According to [Taber, 2000], researchers using grounded theory should maintain an open mind at the start of the research rather than allowing themselves to be “coloured……by expectations based on existing theories”. The method provides an outline for analysing qualitative data by categorising similar responses together. The process can be repeated in order to compare data to previous occurrences until an endpoint is reached (known as ‘theoretical saturation’ [Taber, 2000]) when additional data collection and analysis does not change findings significantly.

3.4.3. Ethnography methodology

As a methodology in engineering education research, ethnography is very unusual. Its origins lie in the research generally associated with anthropology. This is because it was first used by researchers who rooted themselves amongst natives in order to research their cultural ways (how they live within their social situations). The nature of this methodology is such that the quality of the research may be difficult to judge for credible results unless used in conjunction with another methodology for more credible evaluation criteria, as recommended by Case and Light, 2011.

Although we are not applying this to the extent in which the methodology had originally been intended, we have considered the ethnic and educational background and level of our learners for two or three of our case examples.

3.4.4. Phenomenography methodology

This methodology focuses on the individual's point of view rather than the researcher's or a community's. It results from data collection methods in which we seek textual comments in semi-structured interviews or comments on a questionnaire. Instead of looking for common shared experiences of a phenomenon, it focuses on the ways in which learners differ in their opinions. It seeks to maximise the potential variation in opinion. For example, within a group of learners the majority may have indicated that they have favoured collaborative group work yet a small number may have indicated opposition and dislike to it. It has been used in engineering education to investigate variations in the ways students understand important concepts [Ebenezer & Fraser, 2001].

3.5. Procedure for the case studies

3.5.1. Procedure for case study 1

This case study applied a flipped learning approach to teaching and learning by requesting that learners (details of whom are provided in the detailed case study) follow audio-visual (AV) material online prior to delivery. The researcher wanted to determine whether the flipped classroom approach using AV material would enhance the student experience and improve assessment results by means of the AR methodology. I also wanted to determine whether students would become more engaged with the topic material. Viewing the material prior to class should lead to a more discussion-based delivery during the timetabled session. The methods of evaluation included observation (of learners and the practitioner by a peer), feedback questionnaires distributed to students and analysis of the end of year examination results (grounded methodology and phenomenography). The flipped classroom technique is to be applied firstly to one specific topic, which is only a small part of a year-long lecture programme in a manufacturing technology module. After considering the outcomes from the experimental first delivery, I then extended the delivery during subsequent years to several other topics, as part of the same module, for further data gathering (grounded theory methodology). The researcher will apply the spiral of Action Research (Zuber-Skerritt, 2001). On review, I should introduce audio-visual clips during classroom delivery and an electronic voting system (EVS) as part of enhanced discussion based delivery. It was planned that the students attend four complete days of workshop practice, which form part of activity based learning for the same module. Several research questions should be addressed as part of this case study (some are identified in chapter 2, some are identified later in this chapter and also as part of the case study that forms chapter 4). This case study would cover all the six sought points in the AR methodology that were listed earlier (empirical means to questions, link to theory, research questions, chain of reasoning, replicate methodology, disclosure of findings).

3.5.2. Procedure for case study 2

In the second case study I will apply games based learning (GBL) to enhance teaching and learning in 3D CAD mechanical assembly. I sought to determine its effectiveness as learning and/or training tool in mechanical assembly but more specifically in engineering and technology education. Learners will be presented with a polymer resin puzzle and collaboratively asked to assemble it within a time constraint. They will be then asked to repeat the procedure in a virtual 3D CAD environment. The more times they could repeat the assembly, the more points they could score, which would enable them to maintain a position on a real time scoreboard. A pre-requisite of the activity is that students attend prior sessions in CAD assembly. The activity is intended to serve as reinforcement of prior knowledge and skills but in a fun and active way. The methods of evaluation will include peer observation by a colleague during the activity, own observations in student behaviour during the activity, feedback questionnaires distributed to students in order to reflect and report on their learning experience and the activity in general. I will also compare and analyse the results of participants (experimental group) with the results of non-participants (control group) in end of term assessed assembly work. In this case study I will attempt to find correlation in performance and the tariff level of individuals at point of entry to the course. Several research questions will be addressed as part of this case study (some of these were identified in chapter 2 and later in this chapter and further research questions are listed as part of the case study described in chapter 5). This case study would also cover all the six sought points in the AR methodology that were listed earlier (empirical means to questions, link to theory, research questions, chain of reasoning, replicate methodology, disclosure of findings). The activity could be replicated but not in the form of a serious game. Instead of a puzzle I could apply the activity to a simple functional mechanical assembly consisting of a dozen parts. The learning outcomes are broader and associated with a greater number of aspects of the curriculum.

The first activity is to be based on a resin puzzle cube made up of several pieces of dissimilar plastics with their own attributes hence suitability for various engineering applications. This should be incorporated as an added explorative part of the learning process. In view of the artefact used, I will apply the case study methodology within AR. I will later introduce the mechanical assembly which will form another cycle in the AR methodology. The new artefact therefore utilises the case study methodology. Research questions will be addressed for both stages of this experimental activity. Data will be gathered in several ways.

Firstly, through observation; the practitioner will observe the interaction between learners during the activity and a peer observing the whole process, including the conduct of the facilitator.

Secondly, data will be gathered by means of a questionnaire survey, which will offer opportunity for comments.

Thirdly, data will be gathered by means of quantification of assessment results and placing these into the context of academic profiles of learners at entry to the course. This introduced a small aspects the ethnography methodology, in that students cohorts were made up from disparate ethnic, cultural and educational backgrounds and their response to the interventions may have varied (receptiveness and attitude to a different method of delivery).

3.5.3. Procedure for case study 3

In the third case study I will retain the theme of Games Based Learning (GBL) within a studio based activity. The key objective was to take a holistic approach in applying and reinforcing knowledge gained across several modules (both previously and currently). As in case study 2, this also requires collaboration between learners whilst engaging in a practical hands-on activity. Learners will participate in groups of no more than three and will be given quiz cards with several questions that made reference to a physical engineering component or assembly. All components would be present within the design studio (an open learning area) or within a workshop area. Students will be tasked with finding the physical component (whilst remaining together as a group) and addressing the questions associated with the artefact. The question could be manufacturing process, materials, surface finish/roughness or broadly design associated. Learners will collaborate to establish answers (otherwise referred to as co-operative learning) which could be deduced based on existing knowledge or investigated by means of available resources (such as the internet or VLE class notes). The activity will be time constrained and the students will attempt to complete as many component cards as they could, in the available time. Each question would carry a number of points if answered correctly (scores associated with questions will not be given, therefore introducing an element of uncertainty, as some questions carry a negative score if incorrectly answered). Scores during the session will be accumulated for team positioning on a leader board (only the top 50% of teams were displayed on the leader board). The activity will run over two weeks (though it could run for longer) and the groups would be striving to appear within the leader board. As in case study 2, it is intended to reinforce prior knowledge, existing skills (in efficient information searching), promote learning through collaboration but also fun in an active way. The method of evaluation will be through observations in student response during the activity, by the facilitator and feedback questionnaires returned by the students to reflect on their learning experience and the activity in general. I will also attempt to find correlation in performance and performance in an element of assessment that required detailed design skills. Several research questions will be addressed as part of this case study (some of these were identified in chapter 2, later in this chapter and further research questions are listed as part of the case study described in chapter 6). This case study also covers all the six sought points in the AR methodology that were listed earlier.

This activity would apply the AR methodology. It is confined to a code of conduct which is provided to the students in the form of game rules (trading of answers, group separation to cover more components, were not permitted). As part of the AR process, the rules are later revised in order to enhance the activity. Each game card focuses on a different component hence the activity consists of small case studies (case study methodology). Data will be gathered by means of observation, learner feedback questionnaires and quantification of assessment scores for an element of an individual design task submitted at the end of the academic year. The question as to whether I am able to improve assessment results (on the aspect of detail design alone) over successive years would require grounded theory methodology to be applied. Small groups are to be self-selective rather than tutor appointed. Groups form freely on the basis of gravitation due to social and/or cultural compatibility.

As in case study 2, data will be gathered by means of casual observation, learner feedback by means of a questionnaire survey offering opportunity for comments and looking for changes in assessed detailed design work for individual project work.

3.6. Theoretical framework

3.6.1. Introduction to theoretical frameworks

> *"A theoretical framework is a frame of reference that is the basis for observations, definitions of concepts, research designs, interpretations, and generalisations, much as the frame that rests on a foundation defines the overall design of a house" (LoBiondo-Wood and Haber, 1998)*

These will help to provide organisation for the study. Through familiarisation of theoretical frameworks I anticipate to be able to interpret the results. The integrity of this process largely depends on the research-based evidence that the frameworks I am applying hold true. The strength of the research-based evidence (the theory) is generally classed within four levels:

1. Factor isolating – that describes phenomena
2. Factor relating – explaining that phenomena
3. Situation relating – predicting the relationships between/among phenomena
4. Situation producing – control phenomena and relationships.

Whilst theoretical frameworks provide a broad explanation of the relationship between concepts, they are based on a single theory. They start as conceptual frameworks and with much evidence backed research they become well established as theoretical concepts. If we are unable to identify an existing theory (theoretical framework) I may construct a new conceptual framework which may be used to describe and explain the relationship between existing concepts (frameworks). The combination of application of two or more theoretical frameworks gives rise to a new conceptual framework. Therefore, if the research is considering combined theoretical frameworks of problem-based learning, collaborative learning and self-directed learning, I am dealing with a conceptual framework which helps us address research questions.

3.6.2. Application of theoretical frameworks in this research

In chapter 1 the researcher started by considering Bloom's Taxonomy of educational objectives and its Krathwohl's development of it. The revision of this by Anderson to contain verbs is the framework that defines the UK-SPEC. This monitors engineering learning outcomes (competencies). I also identified this as a qualitative process and competence in a particular domain can be subjective. An alternative to Bloom's taxonomy is Biggs's Structure of the Observed Learning Outcome (SOLO) which can also be applied as a framework for classifying learning objectives and student achievement. It is primarily concerned with the cognitive domain. Like Bloom's, it builds on a hierarchical classification in which each level forms the foundation for the next.

We considered Vygotsky's theoretical framework advocating social learning and how I can facilitate this in teaching by constructing active learning communities. It is by interaction and communication with others that we learn in accordance to Vygotsky's framework. The interaction (through discussion, collaboration and feedback) can take place between peers (learners) or between learners and teachers or other experts in order to maximise learning. Vygotsky also claimed that culture plays an important role in determining factors for knowledge construction. The way in which we are guided by Vygotsky's theoretical framework in research is by:

1. Developing Learning Communities

2. Having a Community of Learners Classroom
3. Promoting Collaborative Learning and Group Work
4. Offering Discussion-based Learning (Socratic Questioning Methods).

The instruction that supports such social learning requires that students work jointly on tasks, that they develop across the curriculum, they are given meaningful and challenging tasks and Socratic dialogue is managed for deeper learning. Alongside Vygotsky's theoretical framework resides Lave's Situated Learning framework which followed Vygotsky's work. Situated learning is a general theory of knowledge acquisition and developed on the belief that learning normally occurs as a function of activity, context and culture. This includes situated classroom learning where knowledge is frequently 'given' as abstract and out of context. Lave's framework has been applied in the context of technology-based learning activities, focusing on problem solving skills. The two key principles are:

1. Knowledge needs to be presented in an authentic context, i.e., settings and applications that would normally involve that knowledge.
2. Learning requires social interaction and collaboration.

http://www.instructionaldesign.org/theories/situatedlearning [Accessed 11/3/2016]

Knowle's adult learning theory is based on a theoretical framework that advocates self-direction in learning and in chapter 1 I considered the four assumptions on which such a framework is based. One of these assumptions was further supported by Chickering's experiential learning that advocates concrete experiences, practical applications and active experimentation.

As the researcher is engaged in engineering educational research it would be an omission not to consider John Dewey's educational theoretical framework which is based on pragmatism. Active learning including collaborative, entrepreneurship, practical problem solving and critical thinking amongst other learning styles, hinges on this.

John Gagné's theoretical framework of instruction is fundamental in helping us to identify the essential requirements of what makes a serious educational game. To achieve this I make reference to Gagné’s nine events of instruction. These will be applied in the case studies that are based on gamification. Comparable and similar to Gagné’s nine events of instruction is Kellers’s framework known as ARCS (Attention, Relevance, Confidence, Satisfaction) and was specifically developed with serious games in mind. The ARCS model was illustrated alongside Gagné’s nine events in chapter 2 in order to identify common game design elements.

In the review I also considered Laurillard’s conversational framework (Laurillard, 2002) and identified this as very suited to dialogic teaching and learning in HE for designing teaching environments. The reason for choosing this theoretical framework as part of the first case study is because it could assist learners to see the world of practical engineering (specifically manufacturing) as it really is. I also recognise the significance of Kolb’s experiential learning theory in that it complements Laurillard’s conversational framework. This is reflected in the design of the first case study. It is also evident in the other case studies in that I have attempted to close the gap between theoretical and practical frameworks (see figure 3.1).

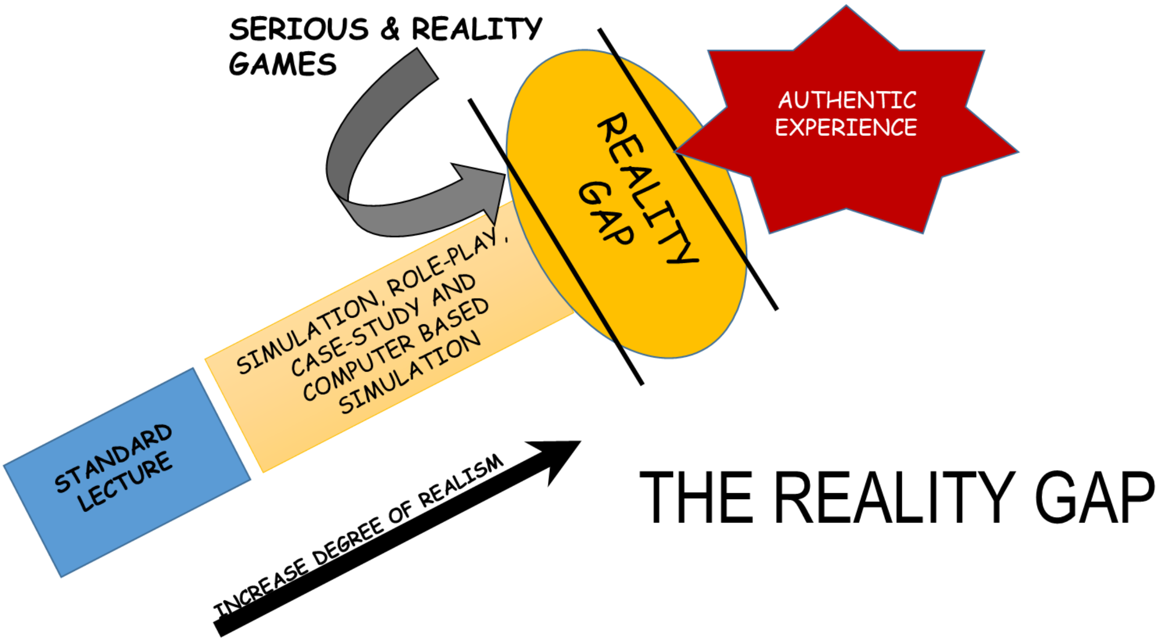


Figure 3.1: Closing the reality gap between theoretical and practical frameworks in teaching and learning

Our practical framework attempts to close the reality gap through the introduction of active leaning. I make reference to two cited frameworks for this; the interactive-constructive-active-passive (ICAP) (Chi, 2009) framework and the knowledge integration framework (or knowledge integration environment (KIE)) (Linn, 2000). Both these frameworks are based on constructivism, (the most prominent schools of thought on how we learn is based on this) in which knowledge is scaffolded in a very dynamic and orderly way. Constructivism was defined earlier (Bruner, 1966), through Bruner's theoretical framework who defined the notion behind his framework on the basis that learning is an active process in which new ideas and concepts are constructed based on current and past knowledge. The structure of cognition should allow the individual to go beyond the given information, according to Bruner (through inquisition and self-direction). This is of particular significance in the engineering design domain.

3.7. What are the key research questions in conjunction with the case studies?

The literature review has considered existing and ongoing research in which the researcher holds special interest due to significance to own work. It has also assisted us in identifying gaps and formulating the key research questions. These research questions are contained in this section and are also addressed fully in the case studies presented in the main body of this thesis and concluding chapters.

3.7.1. Key Research Questions for all case studies

Table 3.1 – Linking the case studies to Research Questions and Applied Methodology

Case study	Description and location	Research questions addressed	Applied methodology
1	Flipped Learning Classroom, chapter 4	General-1, 2, 3, 4 & 7	Action Research Grounded Phenomenography
2	Game Based Learning (GBL) in Mechanical Engineering Education, chapter 5	General - 5, 6, & 7 Case specific - 8-14	Action Research Case study Grounded Ethnography Phenomenography
3	Activity Based Learning (ABL) using Gamification (GBL) in Mechanical Engineering Education: Studio Based Case Study, chapter 6	General - 5, 6 & 7 Case specific – 15-22	Action Research Case Study Ethnography Phenomenography

Table 3.1 links the research questions and applied methodology to each of the case studies. From the outset, there were research questions common to all the case studies. Each case study has raised its own, more specific research questions which are listed below and made reference to in table 3.1. All research questions stem back to the research aims and objectives.

1. Can I quantify the educational benefits of using Electronic Voting Systems (EVS) and express these in terms of improved student learning?
2. Do Electronic Voting Systems (EVSs) enhance the student learning experience?
3. Are learners able to achieve improved examination results in subjects delivered by a revised method of the Flipped Classroom and can they subsequently achieve a higher level of learning?
4. Does the flipped classroom approach enhance the learning experience, through better engagement with the students, compared to conventional classroom-based learning?
5. Is Action Based Learning (ABL) a suitable method of delivery for Mechanical Engineering subjects?
6. Is GBL a suitable method of delivery, assessing and feedback of mechanical engineering subjects?
7. 7. Would a combination (Blended learning techniques) be deemed more suitable for delivery of Mechanical Engineering subjects?

More specifically to each case study: case study 2

8. Had the students applied the skills and knowledge gained in the sessions leading to the event and were skills further reinforced, partly through collaborative learning with their assigned partner during the activity?
9. Which students had performed better and why? Is there a link to prior learning, attendance and qualifications at point of entry in to Higher Education?
10. Had collaboration enhanced or hindered certain competitors and why?
11. Did the activity serve as an effective means of formative self-assessment, to gauge standards of students against peers?
12. Was the activity enjoyable as an alternative method of delivery?
13. Would the activity lead to improved performance in assessment?
14. Was there a link between performance in manual and computer assembly?

Case study 3

15. Were students applying knowledge gained from formal didactic delivery sessions leading to the activity and was knowledge reinforced partly through collaboration with their peers?
16. What were the motivating factors driving the students to perform better than their peers in the activity?
17. Which students had performed better and why?
18. How do students overcome gaps in knowledge through application of other skillsets and collaborative learning?
19. Had collaboration enhanced or hindered certain participants and why?
20. Did the activity serve as an effective means of formative self-assessment, to gauge standards of students against their peers?
21. Was the activity enjoyable and was attainment improved as a result?
22. Would the activity lead to improved performance in assessment?

All research questions addressed, for all three case studies, relate to the three main objectives of the research, which are:

i. To enhance the level of Teaching and Learning provision
ii. To develop suitable interventions to improve teaching effectiveness
iii. To quantify the teaching and learning effectiveness.

Methodologies applied to each of the case studies

Case study 1 - flipped learning classroom

Action Research is at the heart of each of all the case studies as they are practice based and all apply the spiral of AR to some extent (Zuber-Skerritt, 2001), see fig. 2-11. In AR methodology we pursue change through understanding by action and critical reflection and later by refinement of methods, data and interpretation through reiteration. We introduce an intervention which by initially applying a flipped classroom learning to a single topic. This entailed audio-visual study and more discussion led delivery in the classroom with multiple choice questions as a focus. Quantifiable changes in exam performance for that specific subject are evaluated for their significance in impact. Further interventions are introduced covering a wider range of topics coupled with experiential learning and EVS as a means of reinforcing knowledge, reflective learning and formative feedback (for both learners and facilitator). Exam assessment performance is later reviewed based on the interventions. The process of tweaking the process once repeated and comparing data to previous occurrences is characteristic of grounded theory methodology. The group of learners provided feedback and comments on their experience of the revised delivery method and the results were analysed. This is characteristic of the phenomenography methodology and used in previous engineering education investigations (Ebenezer & Fraser, 2001).

Case study 2 - Game Based Learning (GBL) in Mechanical Engineering education

In addition to the AR methodology, in this particular example The researcher uses an artefact which initially consists of a resin puzzle cube (as the focus of the game in GBL) and later an air engine which was more akin to a simple mechanical engineering assembly, forming an excellent case for studying various aspects of mechanical components (such as tolerances, surface finish, manufacturing process etc.). The case study methodology is therefore applied. As in case study 1, assessment results are evaluated for future tweaking to the interventions, therefore grounded theory methodology is applied. Feedback and comments on experience of the activity and delivery method are analysed, therefore phenomenography methodology is applied. In view of considering the profile of educational and ethnic background of the learners and their engagement in this activity (through observation) I also apply ethnography as a methodology, but to a very limited extent.

Case study 3 - ABL using Gamification (GBL) in Mechanical Engineering education: studio based case study.

The AR methodology applied in case 3, the researcher uses numerous (over 80) engineering artefacts to form the basis of studio gaming activity. Each component offers a case example of its own merit. The eighty examples form part of the learning activity (each of merit as a case study in its own right). Future refinement of this activity would allow for greater incorporation of grounded methodology. The case goes as far as evaluating assessment performance (through a single cycle) due to the nature of the activity but does not introduce a reiteration cycle. Feedback, in the form of comments based on experience of the activity are analysed, therefore phenomenography methodology is applied. I consider the profile of educational and ethnic background of my learners and their engagement in this activity (through observation) therefore applying ethnography methodology, be it to a limited extent.

These research questions were formulated at the start of the investigation and designed to question the possibility of improvement in effectiveness of teaching and learning for delivering engineering and technology subjects through varied and blended teaching and e-learning techniques. An indication of success would be an outcome that would encourage students to learn by greater involvement (partly through asynchronous self-directed learning), stimulation and inquisitiveness.

- It is anticipated that this research would widen but retain specific aims leading to quantifiable novel aspects in teaching and learning within the subject area of CAD/CAM and closely associated subjects. This would confirm that no single technique works to best effect with a group of learners, therefore a blend of techniques would be considered in accordance to the learners' knowledge and abilities, desired learning outcomes and nature of the subject delivered.
- From the outset I embarked on a path to consider a number of issues which would allow us to utilise a framework for the analysis of effectiveness of current teaching and learning practices in the mechanical engineering subject area and to develop suitable interventions to improve teaching and learning effectiveness.

Following the literature review, the research questions remain open, as to whether such interventions will improve subject delivery effectiveness on a micro level but also a macro level.

3.8. What are the gaps in knowledge this work is trying to close?

The creative application of interventions for enhanced Teaching and Learning in Engineering and Technology subjects, combining techniques such as active learning, e-Learning and Gamification and evaluation of these.

Development of hybrid teaching strategies which are based on existing frameworks and theories (such as Laurillard's and Kobl's) but with specific application to Engineering and Technology subjects and evaluation of these.

There is evidence of distinct lack of empirical data of the pedagogical benefits of educational games despite the large volume of publications that exist on gamification (Markopoulos et al., 2015).

3.9. Summary

This chapter sets out the justification for the study, the study's research questions, and how the study has been designed to answer them. It considered various research methodologies and their relevance to the study. It addresses appropriateness for each of the case studies. The researcher has provided traceability from research aim and objectives to research questions for all case studies. The researcher has linked each case study to methodology and research questions addressed within each case study, specifically. The creative application of combined research methodologies and theoretical frameworks forms another novel aspect of this research. The next chapter considers the first case study.

Chapter 4 – Flipped Learning Classroom

Case example 1:

This chapter draws on and then builds on the following journal publication which has arisen as part of the work included in this dissertation. It has been extended into further work, post publication.

Mavromihales, M., Holmes, V. (2016). Delivering manufacturing technology and workshop appreciation to engineering undergraduates using the flipped classroom approach. *International Journal of Mechanical Engineering Education*, 2016, Volume 44, Issue 2

4.1. Introduction

Delivery of manufacturing technology and practical workshop based work, on undergraduate engineering courses that engage the learners, is challenging. We present an experimental method of workshop delivery using the **flipped learning** approach, a pedagogical model in which the typical lecture and homework elements of a course are reversed. Video lectures are viewed by students prior to class. In-class time can be devoted to exercises, projects, or discussions as in this case. Learners were asked to observe three Audio Visual clips in preparation for class. The objective was to determine whether the flipped classroom approach can enhance the learning experience, through better engagement with the students, compared to conventional classroom-based learning. The level of student participation and level of success have been established by means of feedback questionnaires from more than 100 participants and peer observation. The results are encouraging and demonstrate that this approach is favoured by the students.

4.2. Background for FC case study

Manufacturing technology and workshop appreciation forms a core module for undergraduates in Engineering and Technology studies. Hence, the module is introduced at an early stage of students' Higher Education studies. A proportion of undergraduate students join degree courses with a good grounding in the practical or vocational aspects of the engineering degree gained through apprenticeships or higher national vocational Business and Technology Education Council (BTEC) qualifications. The BTEC Level 3 Extended Diploma is equivalent to a secondary school leaving qualification and vocational qualification taken in England, Wales and Northern Ireland. The qualification is organised and awarded by the Edexcel examination board within the BTEC brand and it is equivalent to Advanced Level subjects. The UK government's website detailing such qualifications and their equivalence can be found at the following link:

https://www.gov.uk/what-different-qualification-levels-mean/overview

Engineering degree courses at The University of Huddersfield attract students from diverse educational and training backgrounds which can vary from school leavers with GCE (General Certificate of Education) Advanced level subjects, international school leaving certificates/diplomas or baccalaureate to mature apprentice trained or experienced students. GCE Advanced level subjects is the common route of entry by UK school leavers, into University undergraduate courses.

4.3. Challenge

The challenge and motivation of this work lies in educating such undergraduates in manufacturing technology so that they are able to gain a wide appreciation of technology as pre-requisite knowledge and understanding to deal with practical design problems. This rationale applies to all engineering students irrespective of their core engineering discipline (Automotive, Mechanical, Energy, Design etc.), as they all have an association with manufactured goods and the processes involved in making them. The subject of manufacturing technology should therefore be taught effectively. It forms an important part of the curriculum and is clearly defined in terms of learning outcomes within the UK Standard for Professional Engineering Competence (UK-SPEC). Engineering Council website [accessed November 4 2015]. The standard can found at the following link.

http://www.engc.org.uk/engcdocuments/internet/Website/UK-SPEC%20third%20edition%20%281%29.pdf).

The UK-SPEC is based on the demonstration of key competences and is the UK Standard for Professional Engineering Competence. It describes the Science and mathematics, Engineering analysis, Design, Engineering Practice competences in the economic, legal and social, ethical and environmental context, that have to be met in order to attain Engineer status at either Technician, Incorporated or Chartered level.

4.3.1. Structure of delivery of the subject and rationale for changes

Currently the Manufacturing Technology and Workshop Appreciation module is a 20 credits module delivered at foundation level, over a period of one academic year. This involves 24 hours of lectures, 36 hours of practical, workshop based work, and approximately 140 hours of unsupervised study (as a recommended guideline).

Students attend lectures that cover a wide array of manufacturing technology topics and a series of practical daylong workshop practice sessions. Some of the lectures are intended to underpin knowledge gained during the workshop practice sessions. Learning from the lectures is structured such that students acquire a broad knowledge of manufacturing by *remembering* (facts, definitions and terminology) *understanding* (differences in processes and their relevance to the manufacture of disparate products or artefacts) and *applying* to design assignments – in accordance to Bloom’s taxonomy and verbs, as revised by Anderson, (2002).

Bloom's Taxonomy was created in 1956 under the leadership of educational psychologist Dr Benjamin Bloom in order to promote higher forms of thinking in education, such as analysing and evaluating concepts, processes, procedures and principles, rather than just remembering facts (commonly referred to as rote learning). Bloom’s taxonomy is most often used when designing educational, training, and learning processes and it makes reference to three learning domains: Cognitive-knowledge, Affective (attitude or self) and Psychomotor (skills)-the UK-SPEC is based on Bloom’s taxonomy.

Referring to Bloom’s taxonomy, it is evident that understanding and applying in Manufacturing Technology and Workshop Appreciation module are reinforced through the practical sessions which also give students the opportunity to develop their psychomotor skills. This also helps build their confidence in attempting practical hands-on craft type work that they may require in future and also inspire the students, thus also addressing the affective domain.

The combination of lectures and practical sessions are designed to complement each other. Students enjoy being engaged in the practical sessions as they are learning by doing, which forms an important aspect of engineering education. The importance of class based learning can be underestimated by learners.

The challenge for the educator is to maintain a high level of interest through various means. When describing manufacturing processes, visual stimulation during the lecture is important in order assist the learner in the learning process. This can be achieved through use of graphical illustrations and still photographs. Case examples, as well as a collection of DVD or short demonstration films also help further understanding. Wider possibilities for such demonstrations are becoming ever more available through the advent of material available in the public domain such as

YouTube and appropriately vetted and approved websites, as well as other online learning material.

Several publications, over recent years, have scrutinised established teaching and learning methods, such as Euchner (2014). Progressive methods of teaching and learning are being introduced (Salmon, Nie and Palitha 2010) along with disparate delivery methods (Clifton and Mann 2011; Holmes and Gardner 2008; Gupta 2008).

Building on current research and authors' experience in delivering Manufacturing Technology and Workshop Appreciation module, a single topic from the module syllabus has been selected for delivery using this flipped classroom approach. The objective is to establish whether the cohort of students perceive that they are benefiting from an improved learning experience and whether the experience is a more enjoyable process due to greater interaction.

4.3.2. Reinforcing knowledge in a standard classroom and laboratory approach

The selected topic for the experimental session, which forms a small part of the module, was addressing cutting tool materials used for manufacturing applications, particularly within a machine shop environment and in the wider manufacturing industry. Knowledge and understanding gained by self-directed learning, followed by workshop sessions where students are actually witnessing and applying the use of such materials in machining processes. Such knowledge is also applied in future design exercises in which the learner is required to consider the ease of manufacture of designed artefacts.

Good practice has been established by the presentation of review questions once a subject has been covered, including the demonstration films. Review questions offer multiple choice answers which are directed at students at the will of the educator (learners are therefore aware in advance that they may be individually asked to answer questions). This serves several purposes:

1. Maintain the attention of the learner who may be called upon to answer questions
2. Provide the learners with a flavour of what they can expect in an end of year assessment in the form of a timed examination.

3. Provide an opportunity to emphasise some critical issues of the topic covered with key discussion points.

4. Structure the learning session such that some humour is included. This can be achieved by offering a selection of possible answers from possible or probable to ridiculous ones.

Guessing is discouraged through the request of rationale behind the given answer or through a process of elimination such that the given answer is justified. This also helps build an aspect of analysis when reviewing Bloom’s learning outcomes (Anderson and Sosniak, 1994). In examinations, incorrect answers receive a negative score therefore discouraging students from guessing their way through questions associated with topics.

Figure 4.1 illustrates how the majority of current or more traditional sessions are divided. These roughly comprise of one third delivery using PowerPoint slides with illustrations and text. The other two thirds of the session are divided (but not always equally) between audio-visual (AV) demonstrations and review questions. In the flipped classroom approach, students are asked to observe relevant and recommended AV prior to attending with prepared questions. This primes them prior to the scheduled session thus accelerating the learning process.

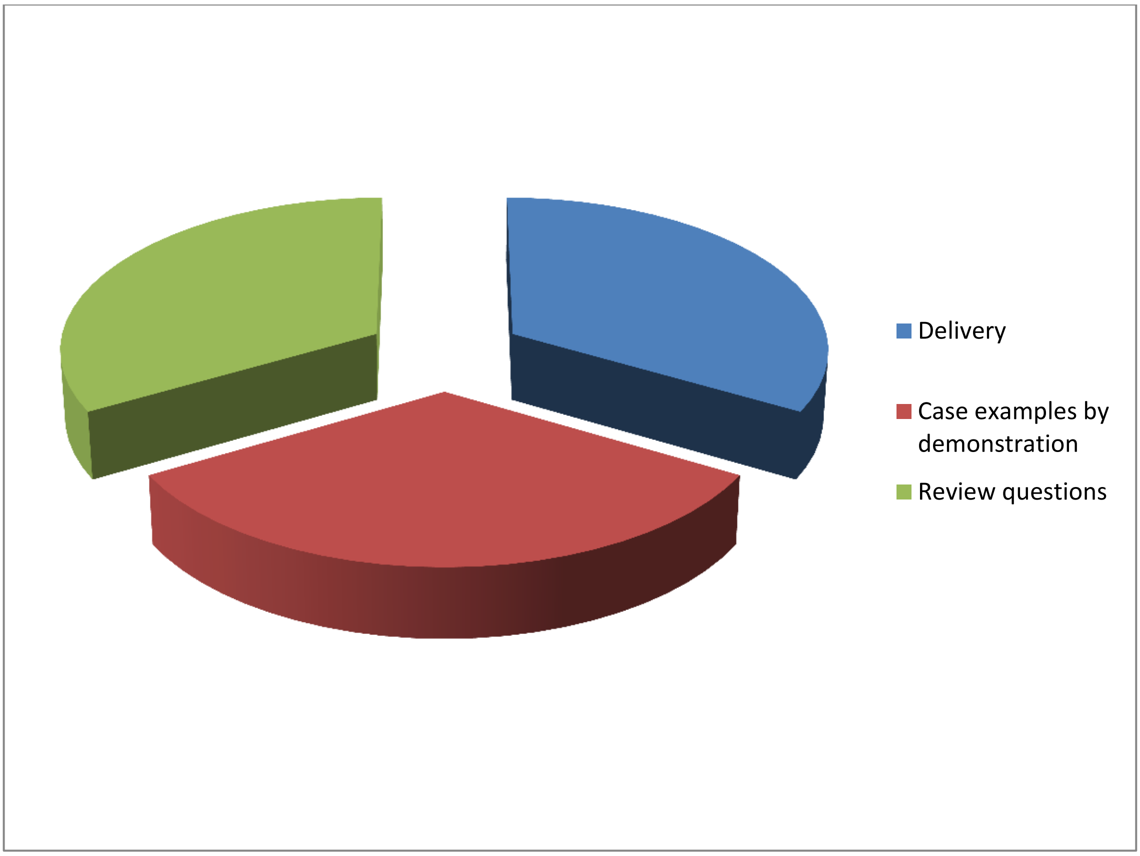


Figure 4.1: Example of how a session is currently delivered. There can be a time variation between each of the three aspects (delivery, case examples by demo DVDs and review questions)

4.3.3. Educational material

The learning material includes PowerPoint slides augmented with detailed notes were developed by the author over the last twenty years. A number of reference sources were used which were also recommended to students for further reading such as a well-established and classic text books in the subject area by S Kalpakjian and S Schmid (2006), *Manufacturing Engineering and Technology* 5th edition, ISBN 0-13-148965-8 and DeGarmo's, (2013) Materials and Processes in Manufacturing, ISBN 978-0-470-87375-5.

Audio visual material was carefully selected by the author through what was judged to be suitably educational and available in public domain through the World Wide Web.

The lecture based material provided to students includes a copy of the PowerPoint slides supplemented by an attached script. The learner is encouraged to make further notes around the slides that provide the main visual aid for the subject covered. Such notes along with the provided script allow for a valuable source of information when it comes to revisiting the subject matter later. Students are also encouraged to purchase one of the recommended text books which will be used as a reference beyond the duration of the module. This is also a source of reference for further student learning.

4.3.4. Workshop exposure

The workshop exposure forms the practical aspect of the module where students are given the opportunity to develop their psychomotor skills. It is important in that it provides a fundamental appreciation in working safely and the development of skills required for the operation of machine tools. These will consist of lathes, milling and other machine tools. Students are made aware during the class based sessions that in the wider world of manufacturing, a plethora of complex machines exists.

During workshop activities, comprising of a total of 36 hours, hand tools are used as part of the practical work for the manufacture of a simple engineering artefact. The students are exposed to the effective use of Computer Numerical Control (CNC) machine tools and appreciate their application in an industrial environment.

4.4. An experimental delivery method of a flipped learning approach

The flipped classroom is a relatively new pedagogical method which employs audio-visual lectures, problems and active group-based problem solving activity. It represents a combination of set of learning theories. The rise of the flipped classroom has been researched by Bishop J et al., (2013), who attribute the rise of the flipped classroom approach to the advent of technological movement that has enabled ‘the amplification and duplication of information at extremely low cost’. The flipped classroom approach entails both inside and outside classroom activities. The classroom activities tend to be more interactive compared to traditional lectures. Experiences and required resources for such a method of delivery in engineering have been described by researchers such as Rossiter, (2014).

Bates and Galloway, (2012) have studied and reported on the approach of the flipped classroom in a large group enrolled on an introductory physics course.

The students engaged in the learning process described in this paper are all enrolled on the module described in section 1.1. The complete group is involved and observed. The longer term objective of this research is to gauge and quantify, by means of changes in examination performance. It is hoped to achieve this by monitoring and comparing performance between subjects covered using the flipped class approach and those covered by more traditional means.

Because of observed students' engagement with visual aids (VA) material during the class, it was proposed that current delivery method be altered to make further use of short demonstrations available within the public domain, particularly on the website YouTube. Students have expressed a willingness to view educational material prior to class and are also better prepared for more interactive engagement during class activities. Such short clips can follow a verbal explanation of a process and accompanied by running commentary by the tutor. The aim is that visual impact short clips will deepen understanding more than a description with simplified diagrams. Simplified diagrams serve the purpose of putting a concept across but can often also cause confusion thus raise questions by the learner. Photographic images, clearer comprehensive diagrams and animations are preferred whenever possible.

Students are often keen to explore such resources outside the timetabled class, particularly with direction and guidance. Such resources carefully selected by the tutor for showing during class, are important because upon delivery of a subject through the imparting of knowledge, students are inclined to form a visual perception of a process which can lead to further curiosity of the subject especially if only a partial understanding is formed. Curiosity in a subject after class delivery is regarded as good because it is a positive sign of stimulation for further learning. The audio-visual demonstrations serve to satisfy this curiosity and also clarify any misconceptions that the learner may have had regarding the context in which the process is applied in practice.

The principle of restructuring delivery of sessions is easier to achieve with certain topics than others. It also relies on the availability of relevant short clips. Bite sized chunks of videos offered within the YouTube environment implies that several short videos from differing sources can easily be accessed. This has proven to work in the delivery of nursing practice education as reported by Clifton and Mann, (2011). By analogy, Engineering and Manufacturing education encompass vocational subjects that can benefit in similar ways of delivery for teaching and learning.

An experimental method offers the opportunity to assess the flipped learning approach. We can then quantify the outcomes by comparison to a usual method of delivery. This may be done by means of questionnaires directed at the students. By firstly selecting just a few (no more than three) video clips and of no more than thirty minutes' total duration, students shall be asked to view these online, prior to the scheduled class. They will also be requested to come to the session with a question based on the viewings. Some of the raised questions may be listed for everyone to see and therefore form focus points to address for discussion. Clarification or explanation of queries may be made on reflection of the delivered session (which will also include short video clips with commentary by the tutor, explanations and expansion where necessary). Godwin, (2007) reports that group discussions stimulated by using YouTube in the classroom environment can lead to deep learning on the subject as well as a critical evaluation in information literacy.

The longer term research question is whether learners can achieve improved examination results in the subjects delivered by this revised approach of delivery and can they subsequently achieve a higher level of learning.

4.5. Educational framework

Our past experience in delivery was a motivation for the experimental session; students often comment on technically inspiring things they have observed either on TV or online. Manufacturing technology is a visually stimulating subject that can appear very 'bland' if described with words and simple sketchy illustrations. This is particularly the case now when learners have been exposed to educationally rich 'Discovery' channels and online sites that are freely available. Author's experience indicates, and is substantiated by Biggs, (2003), that greater learner participation is a recipe for improved learning success. Some prior knowledge, even when limited, can further improve the knowledge acquired during the delivery session, by providing a basic foundation by better utilising the time during the teaching and learning session. This can be further substantiated through an appropriate educational theoretical framework or frameworks. Theoretical Frameworks are 'formulated to explain, predict and understand phenomena' (Swanson, 2013). They can also be used to challenge and extend existing knowledge, within limits of the bounding assumptions, University of Southern California, Research Guides [accessed November 4 2015]. http://libguides.usc.edu/content.php?pid=83009&sid=618409).

Lev Vygotsky's Theoretical Framework on Social Learning Theory has been identified, Educational Technology 547, Learning Theories Website [accessed November 4 2015].

http://jan.ucc.nau.edu/lsn/educator/edtech/learningtheorieswebsite/vygotsky.htm). Social Learning theories help us to understand how people learn in social contexts (from each other) and how teachers act as facilitators to construct active learning communities (Vygotsky, L.S.; Hanfmann, Eugenia; Vakar, Gertruda; Kozulin, Alex, 2012).

Consequently, teachers can create a learning environment that maximises the learner's ability to interact through discussion (discussion of AV case studies and demonstrations in this case), collaboration (group viewing and creating questions prior to scheduled classes) and feedback (through addressing questions in class as points of discussion thus eliminating incorrect answers by reason – a form of formative feedback). In Vygotsky's framework this is discussion-based learning using Socratic Questioning Methods where the teacher or instructor manages a Socratic dialogue that promotes deeper learning (Hake, 1998).

Vygotsky also recognized that learning always occurs and cannot be separated from a social context, therefore the essence here is to encourage learners to be inquisitive by identifying processes discussed in class with everyday artefacts. Through deeper understanding the learner can acquire the knowledge to challenge traditional methods of production by proposing alternatives. In Bloom's Taxonomy this is the Application, Analysis and Evaluation stages in the Cognitive Process Dimension (Krathwohl, 2002).

4.5.1. Timing and evaluation

Delivery of the experimental session took place during the first academic term 2014/2015. Time was allowed to select a suitable subject topic with adequate online resources. Evaluation of the session was by peer observation of teaching, a procedure which forms part of usual internal quality procedure. This can therefore be compared to delivery of more usual sessions for the same module. The primary means of feedback was an evaluation questionnaire given to students to complete immediately after delivery. The Harvard University, Programme on Survey Research Tip Sheet on Question Wording was used as a guide to formulate the questions for the questionnaire. This can be found at the following link:

http://psr.iq.harvard.edu/book/questionnaire-design-tip-sheet (last updated November 17, 2007)

Feedback was also taken in the form of informal discussion, which is sometimes part of the agenda at course committee meetings where a student cohort is represented by a nominated student on the same course. Students were well placed to express their preference of delivery method as they were able to compare to a more usual delivery style of the same module, but for different topics.

4.5.2. Delivery

The subject topic for delivery was - materials used for making cutting tools in the manufacture of components ('Cutting Tool Materials' – see figure 4.2). This was chosen partly due to the availability of AV material on the web. It also forms an important topic within the module that students can find interesting if presented in an appropriate manner. The availability of good quality and interesting material prior to such a flipped learning approach to teaching and learning is important yet not always entirely possible. After some time was spent exploring the web for suitable material, three links on YouTube were identified. These were as follows:

Recommend AV viewing 1: This covers six popular Cutting Tool Materials and lasts 7.5 minutes. It offered a short introduction to the subject which would hopefully lead to the desire to view a more thorough and comprehensive viewing of the next recommended viewing. Students were directed to the following link, which was embedded in an email sent to each student enrolled on the module:

https://www.youtube.com/watch?v=1K2_zb9kQ-8

Recommend AV viewing 2: This forms part of an extensive collection of the BBC Technical Studies series. Now available in the public domain, it remains highly educational. The only anticipated drawback with this clip was its duration of 24 minutes, which may exceed the time some students are prepared to dedicate prior to class, despite recommendation by the tutor – this was something else to be established from the experimental session. The given link was:

https://www.youtube.com/watch?v=GVLP-IXPEt0

Recommend AV viewing 3: This covers two Super-Hard cutting tool materials and is of short duration of 1.6 minutes. The given link was:

https://www.youtube.com/watch?v=tpXd5Dds27w

The students were notified by email, the week prior to delivery, to view the three AV clips. They were also informed during class the week prior to delivery and reminded by a follow-up email the day before delivery.

The total time involved in viewing the three AV links was 33 minutes and it was recommended that they view all three in order that they attend prepared with questions. The aim was that the delivery sessions would develop in to a more interactive session than usual, through pre-prepared questions that would lead to greater open discussion and dialog.

Learners were given a copy of the slides to be presented. Additional supplementary notes were added to the Virtual Learning Environment (VLE) prior to the session, enabling student access to detailed information as covered during the lecture. Although the lecture started in the usual manner with an introduction to subject followed by scope of the session, it gradually became increasingly more interactive than usual. This was because, in anticipation of prior knowledge, it was possible to direct questions to the learners which would sometimes go beyond the reciting of basic knowledge but more to establish their understanding. Questions can sometimes be aimed at testing the students' ability to deduce answers through reasoning based on known facts. This would indicate that within the learners' cognitive domain they are acquiring Knowledge, Comprehension and certain Application (see figure 4.3). In order to satisfy the underlying criteria for the higher order of cognitive domains a number of multiple choice questions were composed, each offering a range of possible answers ranging from plausible to the ridiculous. These offered discussion points through breaking down, comparing, differentiating, distinguishing, identifying, relating etc. (*Analysis*), prior to explaining, interpreting, justifying, summarising, supporting (*Evaluation*), in compliance to Bloom's verbs. The higher order domains are observed in figure 4.3. The ability to create is anticipated later with more practical experience when students are placed in a working environment.

Figure 4.2: The subject topic (introductory slide) that was covered during the experimental teaching and learning delivered session

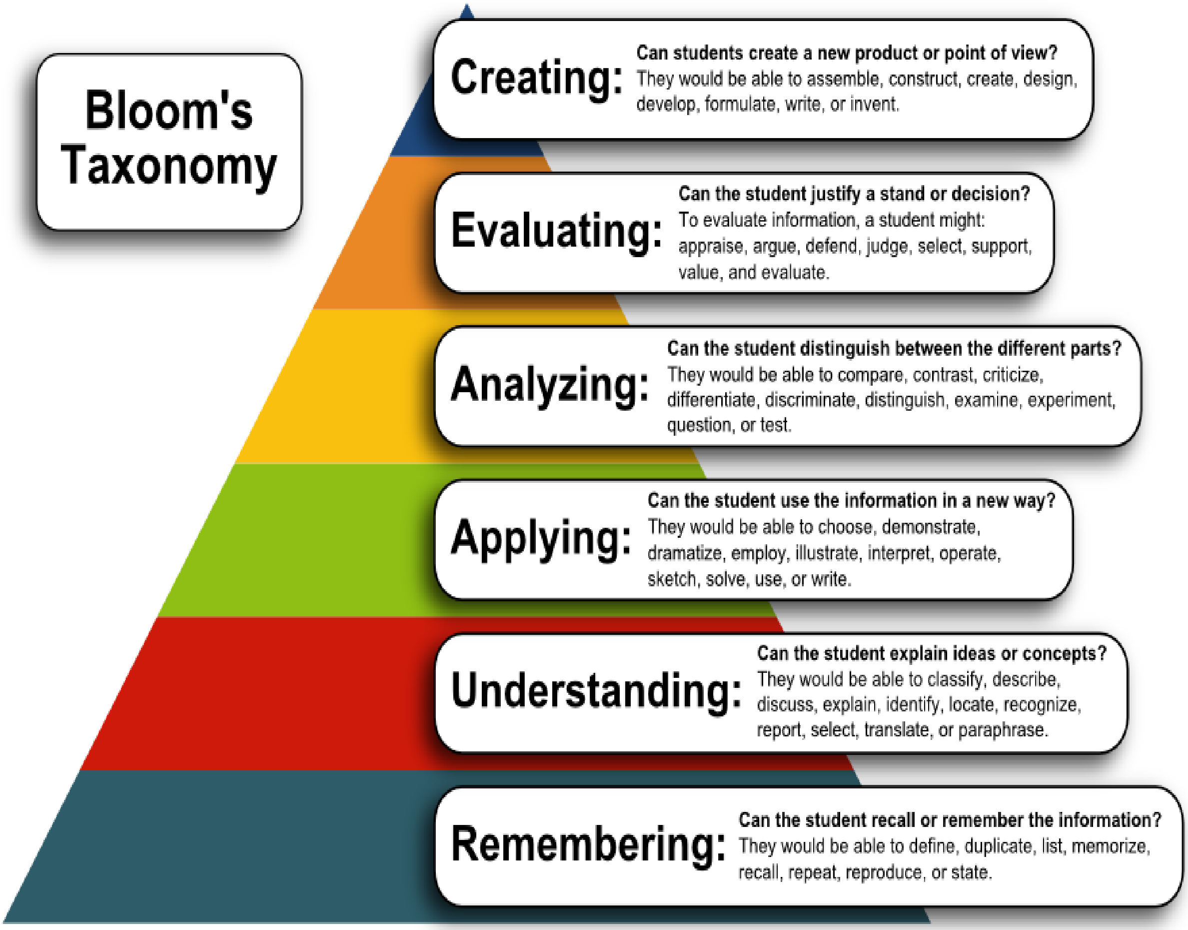


Figure 4.3: Updated Bloom's Taxonomy (2007) Reproduced on 20/2/2020 from http://ww2.odu.edu/educ/roverbau/Bloom/blooms_taxonomy.htm

4.5.3. Evaluation

What remained to be determined at the end of the session was whether the learners felt that they had:

1. Gained a greater depth of understanding by prior viewing of the AV material, compared to not having done so.
2. Had enjoyed and benefited from the session through certain prior familiarity with the subject material, than if they had not viewed it.
3. Had they enjoyed the increased level of interaction during the session.

The means by which to establish the answers to these questions was by a feedback questionnaire, consisting of 10 questions. A copy of the questionnaire is included in the addendum of this paper and the analysis by students' selected answers to the given questions is also detailed.

The theoretical basis of the questionnaire was to establish the actual number of students that were willing to view the recommended material prior to class (and how much of it) and then to hear their views as to whether they had perceived to have gained from the overall learning experience. One of the longer term research questions is whilst students may indicate that they enjoy the flipped classroom approach to teaching and learning, do they actually benefit to a greater extent than a more conventional didactic teaching approach. Question 7 was included to establish the students' perceived relevance of content, to their course. Questions 8, 9 and 10 were included to enable the quantification of participation and to place a value to the number of students who desired for more sessions to be delivered in this manner.

4.5.4. Summary of findings, analysis and conclusions from feedback questionnaire

A total of 104 sample questionnaires were returned by the students that were present in the experimental delivery session. All students on the module took part so there was no selection at this stage of the research. The purpose of the questionnaire was to determine the effectiveness of the flipped learning approach, as perceived by the students and to verify this as part of on-going research. The first question was to establish the proportion of students that attended and prepared for class by having watched the AV material. Of the sample group 51% had watched all three viewings, 30% had only watched some of the three viewings and 19% had not watched any of the viewings (see figure 4.4 for Chart 1). Analyses of these results are detailed in the proceeding sections. The response rate indicated that students are willing to dedicate some time to watching the recommended AV as part of prior learning, but not the entire thirty minutes that was required for viewing all AV material. This was further confirmed when the respondents were asked to provide reason.

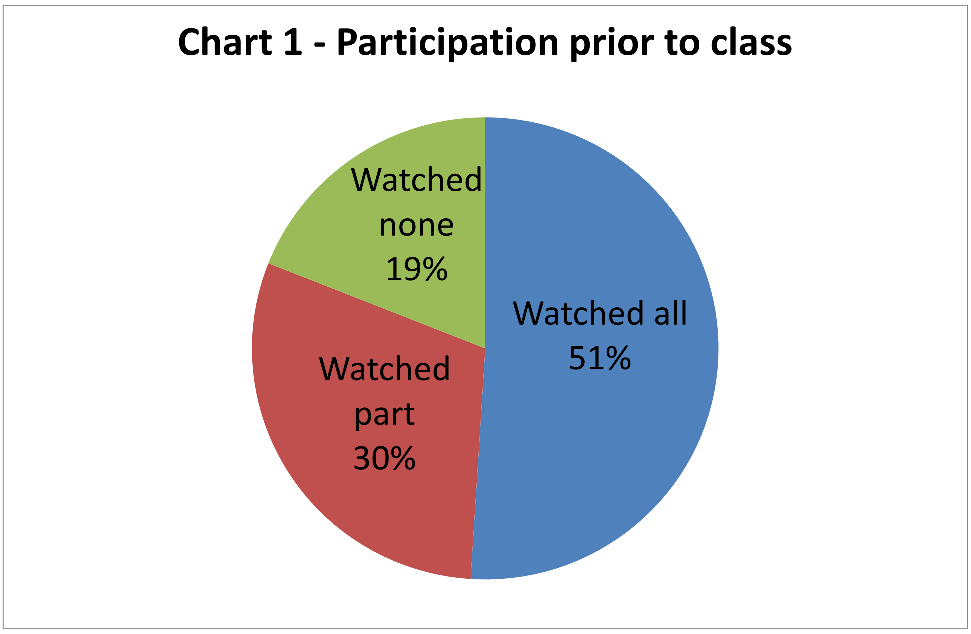


Figure 4.4: Chart 1 indicating the level of participation by pre-class viewing

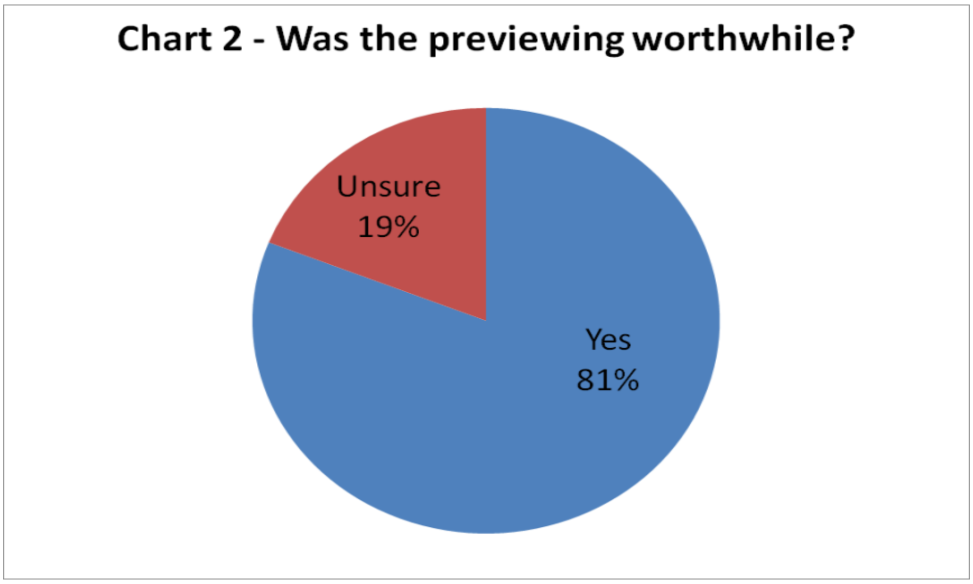


Figure 4.5: Chart 2 indicating the value placed in pre-class viewing of participants.

4.5.5. Students who partially viewed the recommended AV material

Reasons why only 30% of the class watched some and not all of the viewings were identified by further questions and explanations on the questionnaire. Of the 30% respondents who admitted watching part of the viewings, almost all (29%) claimed to have watched only the two short AV viewings lasting 7.5 and 1.6 minutes (a total of 9.1 minutes duration). The reasons claimed were:

They were too long and I didn't have time or didn't want to dedicate the time outside lecture time to view all three and/or lost interest.

This was the response of most students who had not viewed all of the recommended viewings, despite the longest, of 24 minutes duration, being of most educational value as was indicated to the learners.

Students commented that they were under the impression that they did not have to view all three viewings. A false claim as they weren't given any indication that this was the case.

Question 3 of the questionnaire was aimed at establishing whether the learners considered prior viewing worthwhile as a learning enhancing experience. 81% of those that watched some or all of the viewings claimed it was worthwhile, whilst 19% were unsure. The 19% that responded as 'unsure' was an exact match with the 19% who claimed not to have viewed any of the AV material. None of the responses claimed an outright 'NO'.

Asked whether more class sessions should be planned like this by taking the approach of recommended prior viewing, 81% responded with a definite 'YES', 17% were 'UNSURE' and 2% responded with a 'NO'. This is graphically represented by figure 4.6, see **Chart 4.**

Over half (>50%) of these respondents considered the session to be more interactive, more informative and more interesting than usual, partly due to prior viewing. This indicates that overall, students favour this method of delivery because; they claim that it enhances their learning experience.

4.5.6. Students who did not view any of the recommended AV material

Nearly 1 in 5 students or a total of 20 (19%) had not viewed any of the recommended AV viewings prior to the class. Although not entirely surprising, the researcher wanted to identify the reasons by including question 2 in the questionnaire.

The reasons cited for this, as given by the students, included:

'I forgot'

'They were too long and I didn't have time or didn't want to dedicate the time outside lecture time'

'Looked at my email too late'

'Were not interested'

'I didn't know about it'

'Didn't think I had to'

'Already knew about the subject matter'

This would indicate a strong possibility that most of these students have an apathetic attitude to learning and their responses relating to their learning experience, in which comment is invited on an enhanced learning experience, is invalid. Their responses were on whole, indifferent and they failed to participate as interactively as other respondents who had prior knowledge. This was clearly indicated in their feedback.

4.5.7. Students who viewed all of the recommended AV material (see Chart 3)

Over half (51%) of students had viewed all of the recommended AV viewings. This committed them to over 30 minutes of their own time, prior to the class session. Their views and feedback with regard to their learning experience are important as they provide us with greater integrity of the outcome of the experimental delivery method due to this being a better informed sample group than the remainder.

Nearly all the group (52/53 or 98%) had claimed that they benefitted more throughout the session by having viewed the AV material before than if they had not. One respondent was unsure. Yet when asked whether more classroom sessions were preferred to be organised and delivered like this, a fewer number (43/53 or 81%) responded positively with a definite yes and 9/53 or 17% were unsure. 2% said no **(see figure 4.6, Chart 4).**

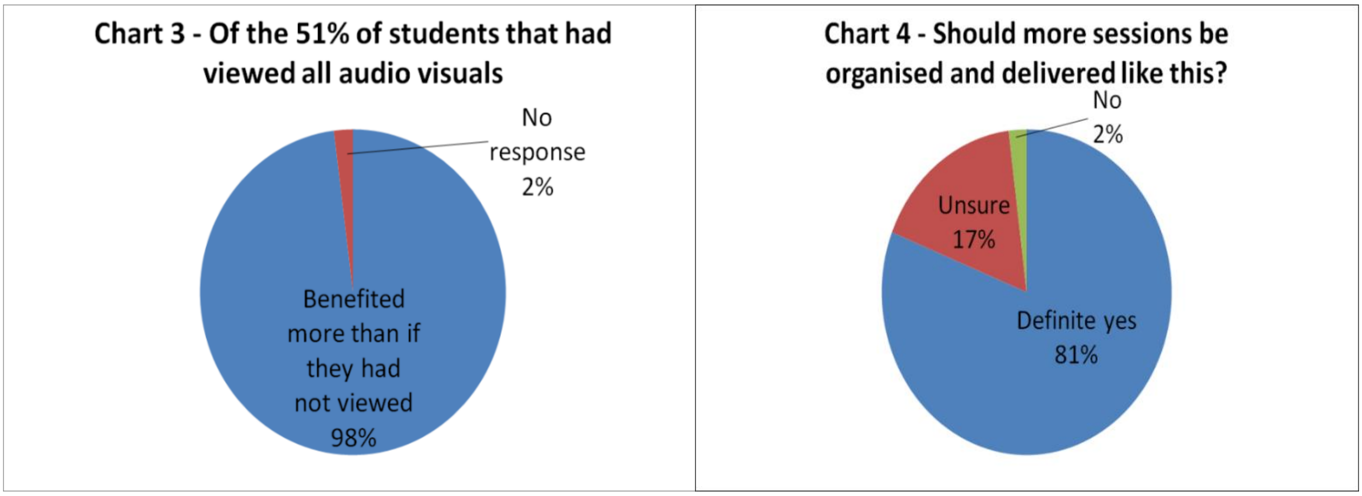


Figure 4.6: Charts 3 and 4, refer to the perceived benefit in viewing all AV (by the students) and whether more sessions should be like this.

Evaluating participation of learners

32% had participated by either direct interaction with the tutor or a peer during the session (either by expressing an opinion, replying to or responding to a question). This is high considering that the group size was in excess of 100 students and the timetabled session of 1 hour. The remainder 36 (68%) claimed that they just listened. None claimed to have lost interest. In the researcher's opinion this was probably due to the size of the whole group.

4.5.8. Subject matter and relevance to the course (Figure 4.7, see Chart 6)

79% considered that it was and 21% were indifferent. None thought it was irrelevant.

4.5.9. Comparison with usual method of delivery (Figure 4.7, see Chart 5)

Of the 53, 83% had agreed that the session was better than usual delivery due to increased interaction between learner and teacher (or amongst peers) and that they considered the session more informative and interesting due to prior viewing. 13% thought it was no different and 4% were indifferent.

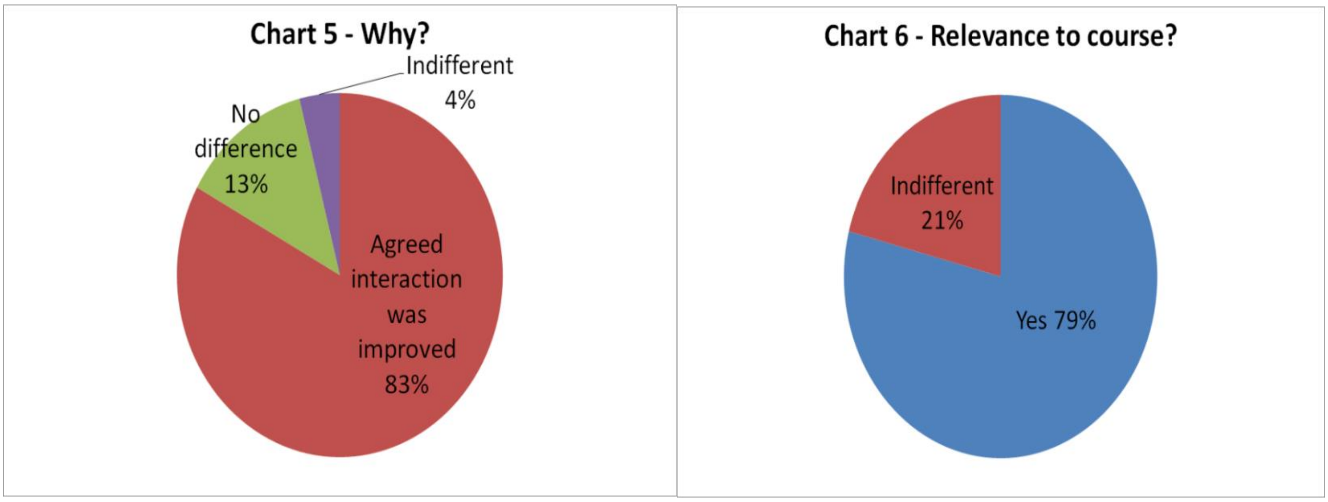


Figure 4.7: Charts 5 and 6 refer to the justification for method of delivery and relevance to course, as perceived by the students

4.5.10. Should future subjects within the module be delivered like this? (Figure 4.8, Chart 7)

74% responded with a positive ‘yes’, 2% with ‘no’ and 24% wanted some more sessions like this but not all future sessions. This is conclusive that the learners were more receptive to the learning experience. Whether they had benefitted from the flipped learning experience would be determined later in assessment results.

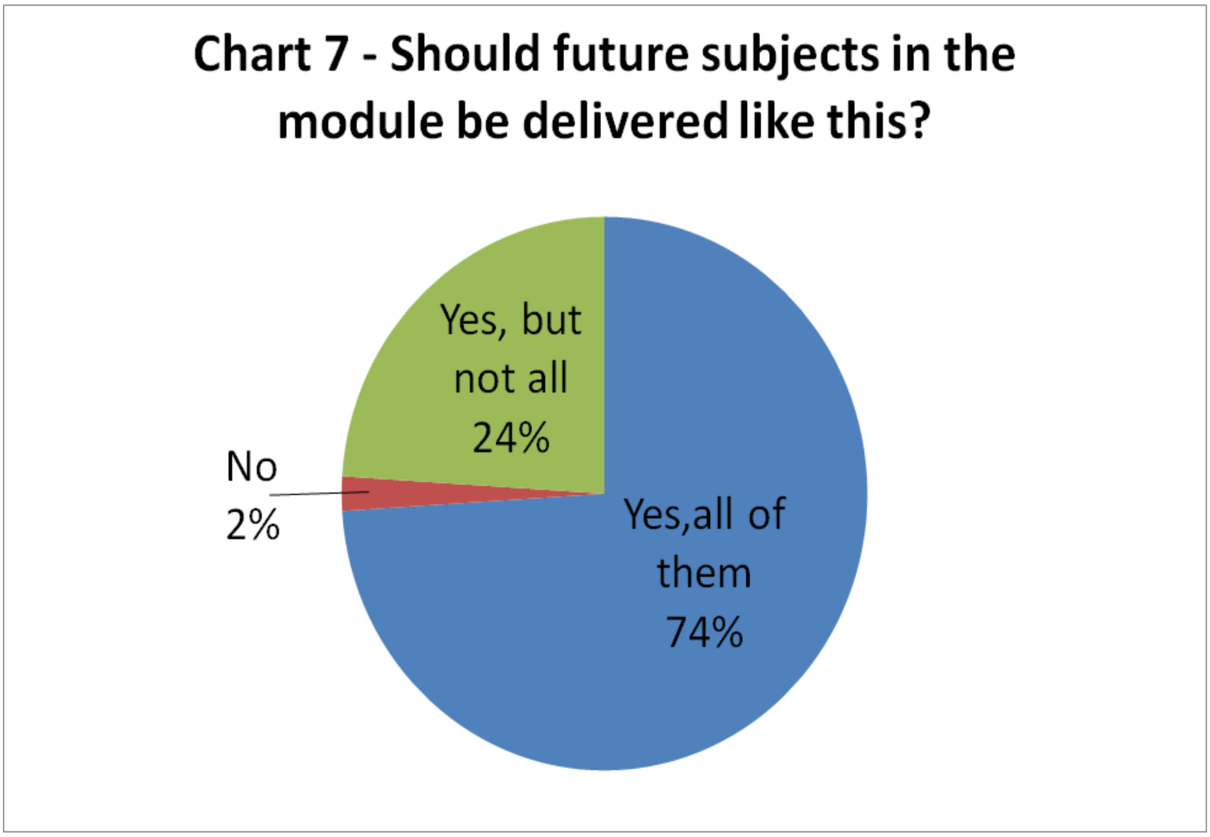


Figure 4.8: Chart 7, refers to the response as to whether future subjects should be delivered like this (in the opinion of the students)

Summary and conclusions of case study 1

Charts 1 to 7 summarise the findings of this research case study. It is evident from this that whist students are prepared to dedicate time for prior learning in preparation for class, this time is limited to less than 10 minutes for a fair proportion (30%) whilst 19% are unwilling for various reasons, including apathy and time constraint. Even of the 30% of students that had prepared with up to 10 minutes of viewing, over 80% considered this to be a learning enhancing experience. 98% of these students thought that future topics within the same module ought to be delivered in a similar manner due to the learning benefits.

A small minority of the group (less than 20%) have an apathetic attitude to learning in that that they were merely prepared to attend timetabled sessions and be informed without a will to participate in an interactive manner or even to undertake some prior preparation. The experimental delivery has been worthwhile in verifying an enhanced learning experience for learners.

More sessions should be organised and delivered in this manner though not all sessions. This should be down to the discretion of the educator and be based on subject and topic. It also depends on availability and quality of material. The group size in this case was large enough to limit the number of learners that interacted in class. It is anticipated that delivery to smaller groups would result in greater engagement by in-class participation, as part of future work. In order to further this work, in the next cycle-propose to introduce a similar experimental delivery to a wider range of topics within the same module. This further work may extend beyond the department in which it is conducted, possibly within another applied science based subject. A similar questionnaire will be issued in order to compare results and attitudes across both subject groups.

4.6. Further experimental work, completed post initial study

In the case study we have detailed the Flipped Learning Classroom. The case study was based on a publication which had arisen as part of the work (see Mavromihales and Holmes, 2016). Several conclusions were drawn from this case study and recommendations were made regarding further work. As a summary of the conclusions and recommendations the following key points were identified, and acted upon:

- The enhanced student learning experience called for more sessions to be delivered using the flipped classroom approach. These would be left to the discretion of the facilitator and would depend on the quality of material available on the internet and through other means (such as the library).
- Although student engagement, participation and overall experience had improved under the revised approach, had student performance under examination conditions also improved? (Specifically for the topics delivered with interventions)
- We had recommended that a greater number of data samples would improve the evaluation and validity of improved performance. It was therefore proposed that the experiment would be repeated in a proceeding year for more topic areas in order to establish whether the

flipped classroom method would yield improved examination results with quantitative data.

- We would thus be in a better position to report on comparisons in flipped learning techniques such as pre-sessional AV and in-class discussions. This would enable us to reflect on and review delivery for future improvements.

4.7. Procedure for extending the research

The case study on which the article was based (case study 1, Mavromihales and Holmes, 2016) incorporated delivery for only a single topic using the flipped learning method of delivery. Despite the reported improvement in the student learning experience, there was insignificant improvement in examination performance in response to the 7 (out of a total of 80) questions included in the end of year examination. The difference in average score for all students between the seven questions covered by FL and the average score for the other 73 questions was less than 2%. This was not sufficiently significant for us to conclude that the method of delivery was performance enhancing for learners.

In a subsequent year the researcher had identified and categorised all topics that were to be covered during the lecture programme. These consisted of nine topics and were as follows:

- Sheet metal fabrication
- CNC machining
- Alternative cutting operations
- Grinding and abrasive machining
- Cutting tool materials
- Surface coatings and finishing
- Metal casting processes
- Welding techniques
- Plastics processing methods.

Once we had searched for suitable and informative AV material we selected the topics for FL delivery. The method of delivery would consist of:

- ➢ Recommending prior viewing and directing students ahead of a scheduled class
- ➢ Initial in-class discussion on the topic with a more dialogic form of delivery which included a set of PowerPoint slides
- ➢ A carefully selected DVD of approximately 20 minutes duration on the topic
- ➢ Poll voting multiple choice questions using EVS with either voting pads of smartphones using the TurningPoint app, which the students had downloaded prior
- ➢ Brief review discussion based on the response to polling.

Should the listed parts of delivery not be covered in a single session then they would carry forward to the next scheduled session. Students were also provided with detailed notes for each subject topic. This was in addition to copies of the PowerPoint slides, in both digital and hard copy formats.

There were four selected topics for FL delivery, which were:

- Alternative cutting operations – which included methods such as laser, electron beam, waterjet and Electro Discharge Machining (EDM).
- Metal casting processes (covering a wide range of processes)
- Welding techniques (for a wide range of applications)
- Plastics processing methods (covering a wide range of processes).

Therefore, four topics would be included as part of the FL delivery method which accounted for a total of 42 examination questions from the 80 that made up the exam. The interventions were therefore applied more rigorously than at first.

Some of the selection of AV material that learners were asked to observe prior to class were found on YouTube and included some of the following:

https://www.youtube.com/watch?v=NE4c1gwzPb4

Blow-moulding demo animation - 34 seconds

https://www.youtube.com/watch?v=8Ql4H40TX_c

Demo of large blow-moulding machine for plastic barrels - 3 minutes 45 secs https://www.youtube.com/watch?v=zcBv_JvFDBI

PVC pipes extrusion line - 3 minutes 15 secs

https://www.youtube.com/watch?v=b1U9W4iNDiQ

Injection moulding animation - 3 minutes

https://www.youtube.com/watch?v=TWEfbGH-Ewc

RIM (Reaction Injection Moulding) manufacturing - 4 minutes 26 secs

https://www.youtube.com/watch?v=-FxiWMnY4aQ

Compression moulding animation demo - 1 min

https://www.youtube.com/watch?v=xOzyaKDbE8s

Compression moulding overview and short demo - 1 minute

https://www.youtube.com/watch?v=wr4_B9EXWSo

How engine blocks are made

https://www.youtube.com/watch?v=dVLrAce8lHE

How engine pistons are made

https://www.youtube.com/watch?v=pwaXCko_Tkw

Sand Casting – Learn more about Sand Casting Process

https://www.youtube.com/watch?v=SIjUVCho_xU

How does laser cutting work – basics explained – 2 minutes

https://www.youtube.com/watch?v=L1D5DLWWMp8

Electrical Discharge Machining – 2 minutes

https://www.youtube.com/watch?v=qZv6DCxTfXI

Different types of welding, in brief – 6 minutes

The DVDs shown in class were of good quality in terms of educational value (in both AV quality and commentary) as they were specifically sourced for that purpose. The YouTube clips were specifically chosen to have a total running time of less than 15 minutes. This was an outcome determined as part of the original study, as students are much less likely to view AV material longer than this in preparation for class.

4.8. Analysis of results

The exam results for each subject topic were analysed and these are displayed with comments in the proceeding Charts.

Figure 4.9, Chart 8 shows the average scores for each examined topic. The overall average score is represented by the straight horizontal line. For this particular year the average exam score was 48%. This appears low which is reflective of the difficulty students have with such a subject that is completely new to them and also the volume of material that is delivered.

To compare this score with past years' results would be futile and fraught as we are dealing with a different cohort of students (a point also identified by Rossiter, 2011).

It is worth noting that, despite an overall low average exam score, the overall student year end score for the module is significantly higher than this because of higher scores achieved during the practical workshop practice attended by the students in which they have the opportunity to be graded quite highly based on practical competencies (skills). The researcher's aim is to increase the overall end of year exam score.

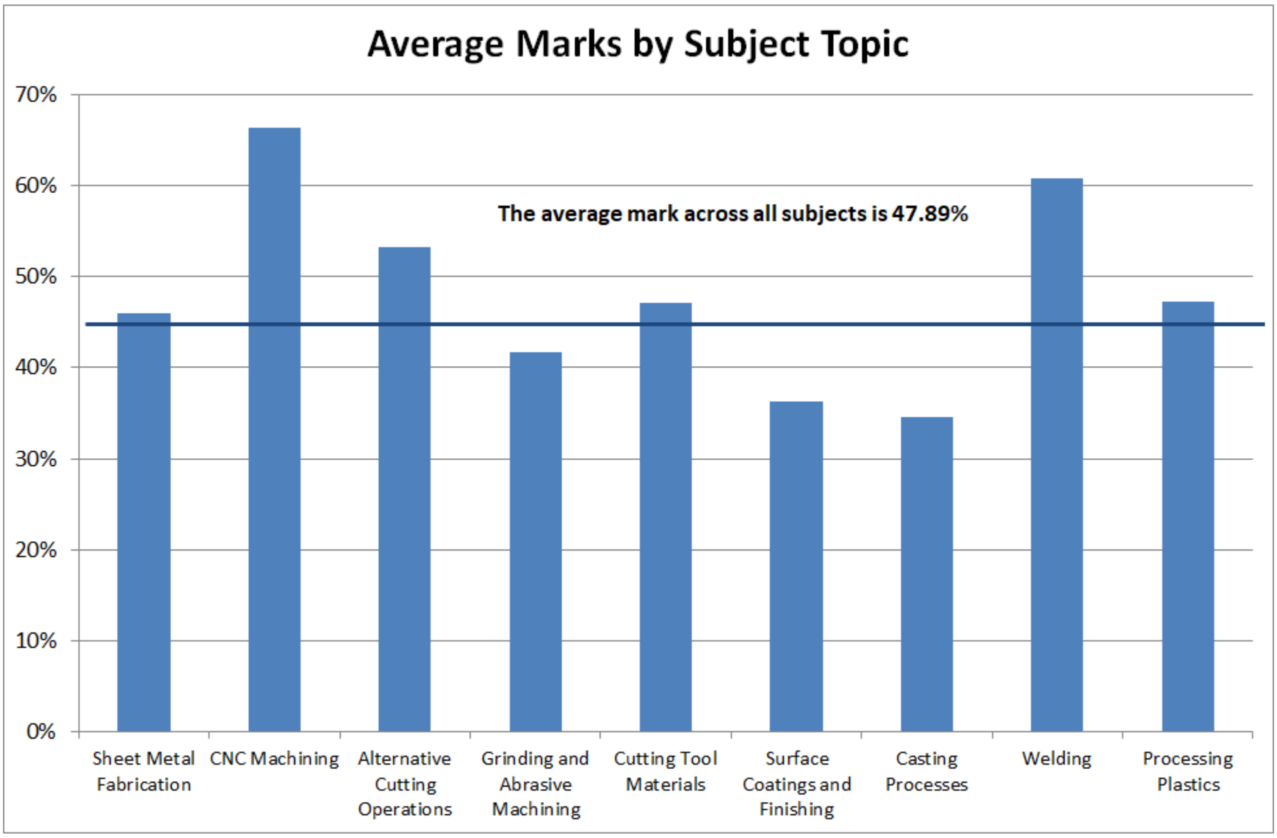


Figure 4.9: Chart 8 - This shows the average scores and overall average score for the entire exam

Our first concern is the topics in which students have scored well below the exam average and seek reasons as to why. It is evident from the graph that there are three low scoring topics:

- Grinding and abrasive machining
- Surface coating and finishing
- Casting processes.

Of these topics only one was delivered using the FL method of delivery and this was, casting processes, which had the lowest average of all topics. We shall therefore explore the exam questions presented to the students and identify the lowest scoring that is attributed to bringing down the average score and attempt to put reason to it.

Three out of the nine questions for this topic (casting processes) had an average score of below 20%. This had lowered the overall score for the cohort, considerably.

The questions (Q.73, 75 & 80) were as follows:

Q73. Which casting method is generally associated with the following selection criteria?

Components with high dimensional accuracy, generally low melting point metals such as Aluminium and Zinc, high output of production.

A. Compression moulding

B. Pressure Die casting

C. Reactive Injection Moulding (RIM)

D. Investment casting

The correct answer is B and only 17% of students had determined this. The question required knowledge based on a good level of familiarity in detail of the attributes of the four listed processes. Answers A and C were not even associated with metals but with plastics. By process of elimination it was possible to determine the correct answer as either B or D. They were unable to answer this due to lack of detailed knowledge across two topics.

Q75. In gravity sand casting, finer sand can result in an improved surface finish of the casting. What may be the trade off as a result of this?

A. The sand mould will not hold together as well

B. Resultant stresses locked within the casting with possibly surface fractures or tear

C. The geometrical integrity of the casting is lost

D. There is no trade off as the quality is improved with no negative effect

The correct answer is again B and only 13% of students had determined this. Again the question required detailed knowledge of sand casting to a level that was not covered in the AV material but only acquired through the notes and then deduced based on known facts. This would indicate that the majority of learners simply skim the surface and do not delve into detail required through reading and probing.

Q80. Which method of manufacture is associated with the production of artificial hip and knee joints?

A.   High pressure die casting

B.   Centrifugal casting

<u>C.   Investment casting</u>

D.   Either low pressure or sand casting

The correct answer is C and only 11% of students had selected this. The question required sound knowledge of all four processes. The answer was also covered as a given example towards the end of an education DVD, during class, which was approximately 20 minutes from the beginning. The low score in this question indicates similar reasons to question 77 (lack of delving into detail) but also a lapse of attention span after a certain period of time.

Similar issues were identified with the other two, low scoring topics. Three out of the ten questions in surface coating and finishing had an average score of below 20%. This had lowered the overall score for the cohort, for this topic, considerably.

Our next analysis was to consider a comparison in scores between questions associated with topics in which we had introduced interventions using AV and the FL approach. Figure 4.10, Chart 9, illustrates the scores by topic for each of the two types of delivery (with and without interventions). It also shows the overall average score for each type of delivery.

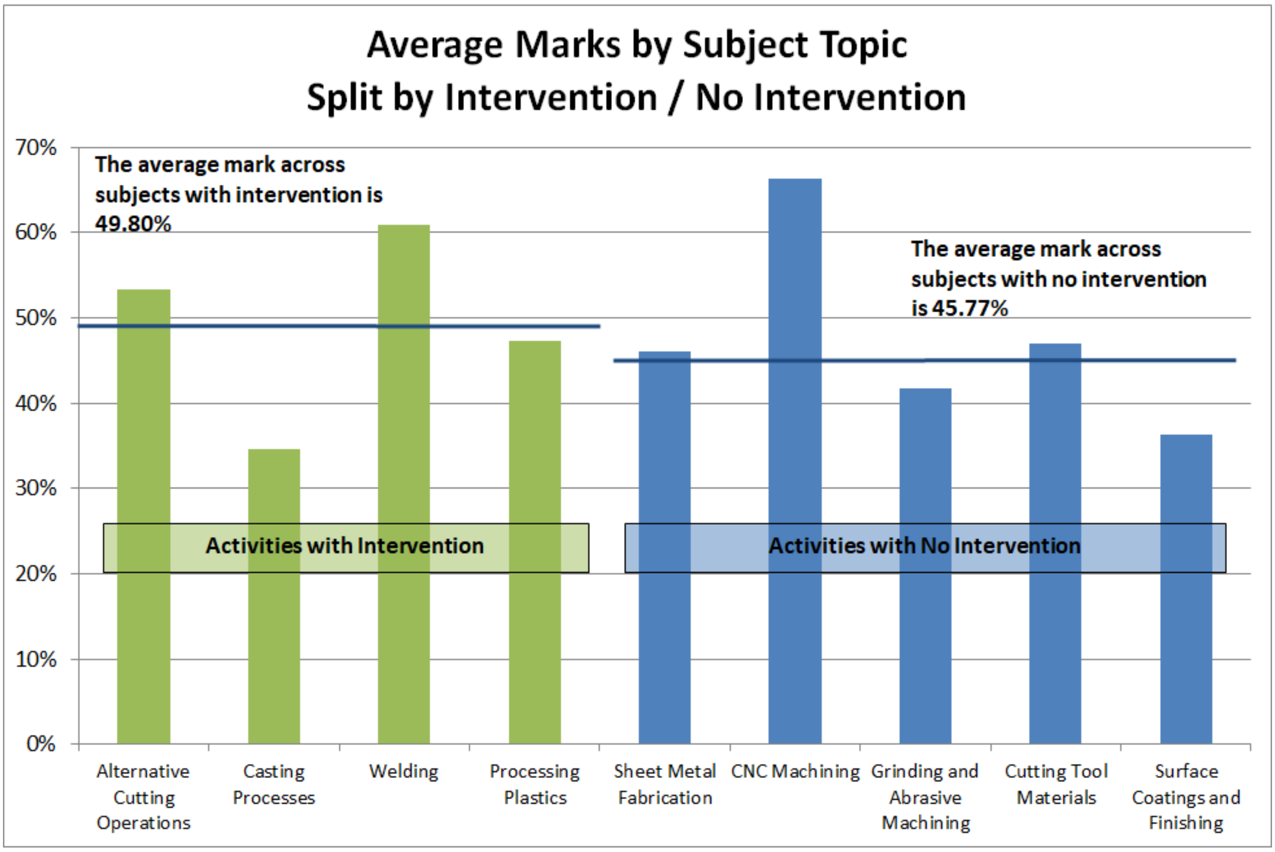


Figure 4.10: Chart 9 - this shows the average scored for each type of delivery method. The four columns to the left have interventions in delivery whilst the five columns to the right have no intervention

With reference to the Chart shown in figure 4.10, Chart 9, we are able to draw some rationale. The first is that despite the method of delivery there is a significant low scoring topic for each. Within the green range of columns, where there were interventions, casting processes had lowered the overall average score. Within blue range of columns, with no interventions, surface coatings and finishing had lowered the overall average score. The reasons for these low scores were identified earlier and put down to lack of in-depth detailed knowledge across the entire topic. This can also lead us to assume that lack of detailed knowledge leads students to think that there is ambiguity in certain questions (in that there are two possible correct answers).

Another rationale that can be drawn is that despite each of the two methods of delivery having low scoring topics, where interventions have been applied the overall score across all topics is 4% higher (50% Vs 46%). Improvements of at least this order are also reported in Freeman et al., (2014), who carried out a meta-analysis of active learning in STEM subjects, which further substantiates the result.

In the final analysis the researcher explores the results in order to try to identify the common factor that links the highest scoring topics.

The three highest scoring topics in order of highest to lowest are:

1. CNC Machining (5 questions, average score 67%)
2. Welding techniques (10 questions, average score, 61%)
3. Alternative cutting processes (11 questions, average score, 54%).

Figure 4.11, Chart 10, illustrates all the examined subject topics divided into two categories. The first category is represented by the green columns and represents the two topics in which learners had gained some experiential learning though workshop-based practice (activity based). This was skills based and entailed two complete and separate days of attendance for each topic, (four days, in total, within a workshop environment) at a technical college. No detailed knowledge was provided during the practical sessions. Blue columns represent all the remaining subjects without experiential learning. The difference between the two, in terms of examination performance, is 19%. This is quite a significant difference which can draw us to a safe conclusion that despite the skills based learning outcomes of workshop practice; it motivates learners for greater inquisition of topic detailed knowledge. Perhaps this is because they are able to see the relevance of the topic in a practical context.

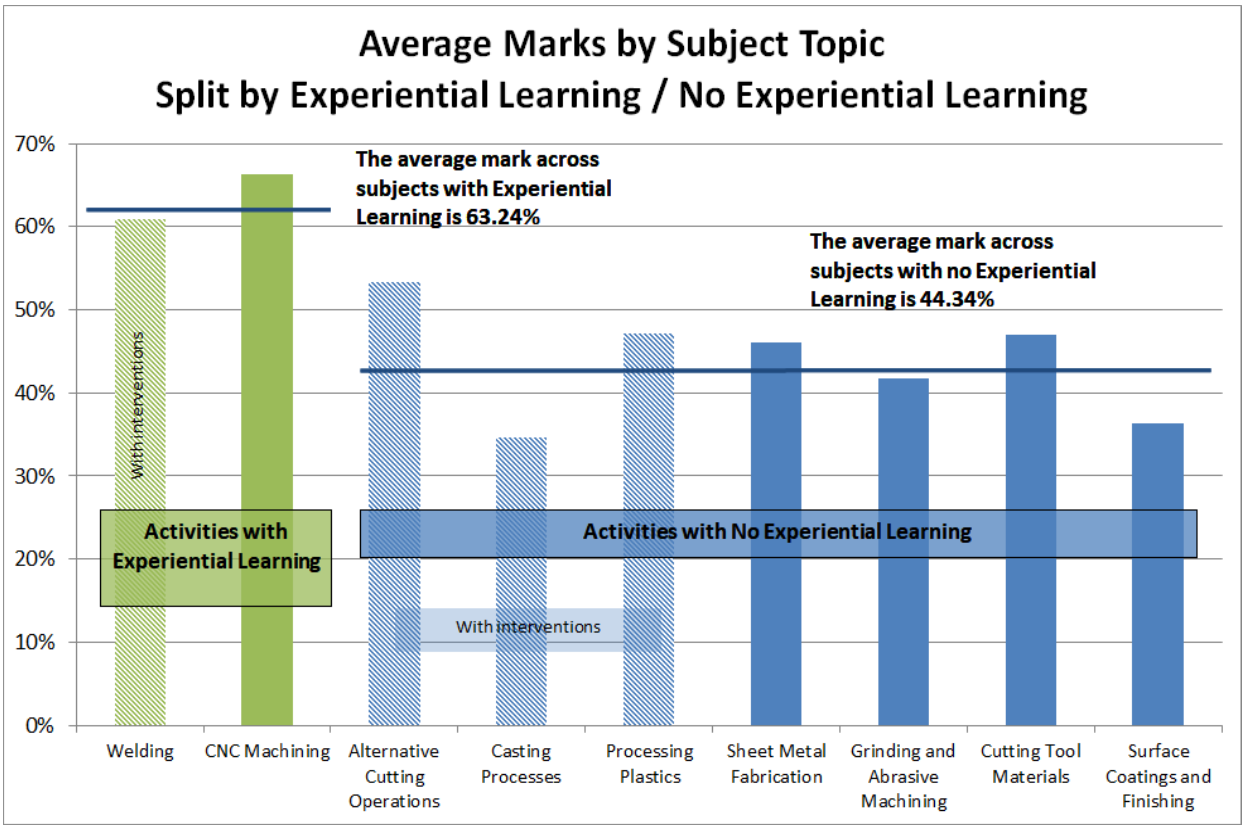


Figure 4.11: Chart 10 - this illustrates a Chart in which all the examined subject topics are divided into two categories. In green are the topics in which students have gained from experiential learning (activity based). The blue columns represent all the examined

Interventions in class delivery method that utilises the Flipped Learning method has helped in improved learning and assessment results. It has certainly enhanced the student learning experience. Experiential learning combined with class-based interventions has made a significant difference in the overall cognition and higher order learning, as is evident from the green columns in figure 4.11, Chart 10.

4.9. Conclusion that can be drawn following the analysis

Some topics are more interesting than others in that they capture the imagination of learners and are more intriguing to them. Alternative cutting processes is one such topic as it includes machining with lasers, abrasive water jets and sparks (in spark eroding).

Ii is the researcher's view, through observations during several years, that the younger learner is not concerned with in-depth detail and breadth of subject knowledge. This takes time and is deemed to be futile because information can be obtained just-in-time as and when needed on the internet. Such knowledge requires dedicated time; something that young learners are not accustomed to and not prepared to do in a fast paced world of instant information (Prensky, 2001). This observation was reported by Prensky, (2001) and in agreement with the researcher's.

Experiential learning is invaluable in complementing subject knowledge despite the learning outcomes being skills based. It promotes deeper understanding and acts as a catalyst for deeper knowledge and understanding from more common class-based delivery, irrespective of whether delivery is dialogic or didactic based. A good example of where this works well is in the training of medical practitioners (combining practical hospital based work and class-based learning). There are several other examples of this (such as dentistry and podiatry). Higher Education in Engineering goes part way to meeting this requirement but falls short of a more rigorous stance. This may be partly due to economics whilst in medical applications the consequences of lack of knowledge with combined skills are regarded as being more critical (Barrows, 1986, Perrenet et al., 2000, Beaty, 2003)).

The improved results that have arisen from action learning (experiential workshop practice) combined with active learning (flipped classroom delivery) support the knowledge integration framework (KIE) (Linn, 2000) as reviewed in chapter 2. According to this framework learners construct knowledge by continuous evaluation, reviewing, refining and developing ideas received from training and observations. The framework describes knowledge integration as a dynamic process of linking ideas and theories in order to rationalise concepts. Observation is something that was actively encouraged during delivery.

A blended learning approach to teaching and learning that utilises the Flipped Classroom approach can yield improvement in learning and higher order thinking but must not be considered in isolation from other delivery frameworks. It must be periodically reviewed to a detailed level in order to consider shortcomings which can lead to further enhancements in delivery. This methodology is also compliant to the action research spiral (Zuber-Skerritt, 2001) which was reviewed in chapter 2 and with other AR methodologies which pursue change through understanding by action and critical reflection and later by refinement of methods, data and interpretation through reiteration (Dick, 1991).

The Flipped Classroom delivery enhances the student learning experience resulting in a greater class engagement. In the case study learners have expressed great satisfaction in this method. The researcher has made a case here that the benefits, in terms of assessment performance, are disproportionate to the hype, often reported by other researchers. But they do enhance the learning experience which is largely what today's fee paying learner expects.

4.10. Summary

In this chapter, we have presented a first case study which is based on delivery of an undergraduate module on manufacturing technology and workshop practice. Although it starts as an action research project, it later reviews data as part of an evaluation process of interventions. The methodology used is therefore primarily AR and grounded theory. Both qualitative and quantitative results have been obtained and these are analysed and discussed. Chapter 4 is self-referenced as it is based on an earlier publication.

Chapter 5 – Game Based Learning (GBL) in Mechanical Engineering Education

Case example 2:

This chapter is primarily based on the following publication which has arisen as part of the work included in this dissertation, which has since been extended to further work, post publication, included in this chapter.

Mavromihales M., Holmes V., Racasan R., Game-based learning in mechanical engineering education: Case study of games-based learning application in computer aided design assembly, *International Journal of Mechanical Engineering Education* April 1, 2019, Volume: 47 issue: 2, page(s): 156-179.

Article first published online: March 21, 2018.

5.1. Introduction

In case example 2 we aim to evaluate the effectiveness of Games-based learning (GBL) within a Computer Aided Design and Manufacture (CAD/CAM) undergraduate module. Although widely used in a selection of subject areas, there appears to be limited application of GBL in Engineering and Technology (E&T). Its effectiveness as a learning or training tool, especially in Mechanical Engineering subject area, has been unclear. This research case example follows on from previously presented research in novel approaches in delivery of engineering education. Games-based Learning has a potential to enhance student experience and the learning process. In order to evaluate the outcomes of GBL approach and observe its effect on students' performance, a simple in-class game on assembly topics was designed and implemented as part of a laboratory exercise. There were two groups of students considered in this case study: the student group "playing" an assembly game (experimental group) and the group which did not experience GBL (control group). The results of the assessment element in the experimental group were compared to the control group. The total number of students including the control and experimental groups was approximately 120 students. The work evaluates both the qualitative and quantitative data established from CAD assembly delivery using the game, and delivery using conventional method. In addition, the comparisons were made between the entry level in to Higher Education in terms of tariff points level (academic score) of participants and educational background. It thus concludes on the effectiveness of the Games-based learning process in Mechanical Engineering Education.

5.2. Background to GBL case study

Games-based learning (GBL) has been widely used in a selection of subject areas within the Higher Education (HE) sector, especially Business. There has been a significant rise in published work on the subject of gamification to enhance engineering teaching and learning during the last seven years (Hamari J et al., 2014, Seaborn K and Fels DI, 2015). Despite the significant rise of research in this area and the positive effect in engineering education, there appears to be a distinct lack of empirical surveys (Markopoulos et al., 2015) and quantitative analysis for the value of gamification effects (Kim S, 2013). In Engineering and Technology (E&T), its effectiveness as a learning or training tool, especially in this subject area appears to be largely unclear. Some research supports the view that GBL learning and attitudes towards it are rapidly changing. Therefore, the primary aim of this research is to evaluate the effectiveness of GBL within Mechanical Engineering specifically within a Computer Aided Design undergraduate module.

In order to evaluate the effectiveness of GBL a Resin Puzzle game was designed and integrated into a delivery of Computer Aided Design activity. We report on the outcomes of this investigation.

The Resin Puzzle game has been incorporated as part of an intermediate module (year 2 of engineering undergraduate study) on a BEng Mechanical Engineering course. The aim of the game is to partly fulfil the learning outcomes of a module in CAD/CAM. These are:

- To demonstrate an understanding of the various CAD/CAM technologies and the various categories of 3-D modelling systems, their application in industry (knowledge and understanding).
- Be capable of undertaking a variety of engineering design activities and design tasks on industry standard CAD systems (abilities).
- To demonstrate knowledge of individual elements of modern design concepts and methods (knowledge)
- The students must also be able to identify key areas of design analysis (such as material selection) and choose appropriate methods for their solution in a considered manner (ability in cognitive and intellectual skill)
- Operate in a situation of varying complexity and predictability requiring the application of an appropriate technique of modern design (ability - practical skill)
- Select and use of a communication method appropriate to the product design analysis (a key transferable skill)

5.3. Research questions

There were a number of research questions to be addressed as part of this research in to GBL. There were:

- *Is there a correlation between the students who performed in the higher finishing positions at the end of the gamification event and their end of year assessment element in assembly?*
- *How do absent students perform in their end of year assessment element in assembly compared with the students who take part in the gamification event?*
- *Do the students who performed in the higher finishing positions, in the game, enter Higher Education with a greater number of tariff points compared to the lower finishing and non-completing students?*
- *How does the year group perform in comparison to the previous year's group where no such activity was incorporated in delivery?*

Although the CAD system planned for this activity was Solidworks 3D CAD, the activity can be adapted for any 3D CAD system in order to achieve the learning outcomes.

The design of the resin game followed current guidelines supported by previous research.

5.4. Game development and applied pedagogy for enhanced game-based learning

The game development for engineering education is a challenging task.

Even if a game is built on sound pedagogical foundations and incorporates proven educational practices, if it is not fun or otherwise engaging, it will fail to meet expectations of both the developer and the end user. By contrast, if game design dominated the process such that the game primarily focused on entertainment, fun and winning, it may fail to apply key pedagogical principles and players, despite being entertained, may have left lacking in knowledge and not achieved any of the learning outcomes.

The danger lies in forcing perceived learning requirements and traditional teaching practices into the game thus disturbing the riveting interactions of gameplay.

A game may therefore easily distract players who may be enticed by the use of high-end graphics and animation, or by competing, scoring and winning, rather than learning. Hiruni and Stapleton describe a systematic process for designing serious games that integrate common instructional systems design (ISD) tasks with a game development process to optimise game-based learning.

Hiruni and Stapleton put forward a case for instructional games to be applied at four levels in order to optimise learning. It is also suggested (Driscoll, 1994) that instruction may be viewed as a series of events that are intentionally designed to facilitate learning and achieve specified learning goals. In terms of educational games, at instructional event level 1, for instance, the game may be designed to facilitate one specific instructional event within an instructional unit or lesson. An instructional game, for example, may be designed to facilitate recall of factual content or to promote active involvement and discussion (Demsey, Lucassen, Haynes & Casey, 1996, Blake and Goodman, 1999). At instructional event level 2 a game may address two or more events contained in an instructional unit. For instance, a game may present learners with a scenario to engage their interest and ask them to explore related concepts through a series of readings and activities. Additional events such as learner assessments and feedback may have to occur before and/or after gameplay to facilitate learning. Such methodology appears to draw correlation to Bloom's Taxonomy (Bloom, 1964).

A framework that helps illustrate how the results of fundamental Instructional Design tasks may be used to facilitate the design of instructional games was proposed by Stapleton and Hughes (2006). Key components in a game were proposed as follows:

Story

- **WHY** should I care, from the player's point of view?

Game

- **HOW** do things work (procedural or mechanics)?

Play

- **WHAT** am I doing (how do I participate)?

According to Hirumi and Stapleton

> *'By applying pedagogy and knowledge of the subject matter, learners, and instructional context to answer the questions, designers flesh out the core game plan and reconcile game and learning goals so that the entertainment supports the learning and the learning enhances the entertainment. The more the learning content and objectives are interwoven into the entertainment elements, the more the game will reinforce the learning objectives.'*

Both Instructional Design (ID) and video game development (GD) processes consist of comparable phases. Table 5.1 below identifies key tasks associated with each phase of the ID process (Hirumi and Stapleton, 2010). The third column provides examples as to how this relates to own case study.

Table 5.1: Applying Pedagogy during the Game Development Process - ID Process and Tasks, adapted from (Hirumi and Stapleton, 2010). Third column added draws relation to my case study

Analysis Phase	*GD Process and Products*	*Example as to how this relates to own case study*
• Assess needs and identify goals(s) • Analyse goal(s), learner and context	• Prepare pitch document • Prepare game concept document	Suitable artefact(s) considered Logistics, timescales considered What knowledge and skills are we reinforcing?
Design Phase	*Pre-Production Phase*	
• Generate, cluster and sequence • objectives	• Create game design documents	What are rules of engagement? What are the learning outcomes?
• Determine learner assessment method	• Prepare art bible and production plan	Formative assessment during and after activity
• Generate instructional strategy	• Create technical design document	Instructional strategy
• Select media		3D CAD as a media
Development Phase	*Prototype and Production Phases*	
• Acquire materials or outsource development	• Develop analogue or low-fidelity prototypes	Acquire the required number of resin puzzles
• Create flowcharts and storyboards	• Develop tangible prototypes	Try the activity on a small scale before rolling out
• Generate prototypes	• Produce Alpha Version	Run and review
• Formatively evaluate and revise material	• Produce Beta Version	Refine and repeat- consider a different artefact
	• Produce Gold Version	
Implementation and Evaluation Phases	*Post-Production*	
• Deliver and manage instruction	• Generate and release subsequent versions	Based on previous stage new beta version is released
• Plan and conduct summative evaluations	• Generate and release upgrades/expansions	Consider further upgrade based on more realistic mechanical assembly

Inevitably, the tools, tasks and techniques used during each phase of game development may vary by project and/or subject area but the phases remain basically the same. It is important to note that the design of instructional games differs from entertaining games in that they are designed intentionally to facilitate achievement of specific learning goals and objectives. Application of pedagogy is necessary to facilitate achievement and optimise games-based learning. Hirumi and Stapleton make a strong case that pedagogy is necessary to facilitate achievement and optimise games-based learning. During the concept development, the selection of basic instructional support provides valuable insights into how content information is to be presented to learners.

Aamodt and Plaza (1994) identified that game based learning can be based on a one or more principles of learning (behavioural, cognitive information processing, constructivist learning or brain-based learning). They addressed the question as to whether games should apply a specific instructional strategy, model or theory, such as case-based reasoning, Learning by Doing (Schank, Berman & Macpherson, 1999) or Problem-Based Learning (Barrows, 1985). The selection and application of the instructional approach is critical as it ultimately affects the manner in which learners achieve specified learning outcomes.

For a constructivist approach to a game, a “story” may present learners with a scenario or problem and the “game play” may require learners to utilise various tools to access content information, derive meaning, and construct their own knowledge of how to work through a scenario and/or solve the problem. Details of how the game will apply key principles, tools and events associated with a particular approach need to be defined at an early ‘pre-production’ stage. By basing early entertainment development on pedagogy, further creative choices in the game development will tend to enhance achievement in learning objectives.

Table 5.2: (Hirumi and Stapleton, 2010) outlines events associated with alternative instructional strategies which are based (or strongly linked to) learning and instructional research theory

Adaptive Instructional Design (Schwartz, Lin, Brophy & Bransford, 1992)	**Collaborative Problem-Solving** (Nelson, 1999)	**Learning by Doing** (Schank, Berman & Macpherson, 1999)
1. Look Ahead and Reflect Back	1. Build Readiness	1. Define Goals
2. Present Initial Challenge	2. Form and Norm Groups	2. Set Mission
3. Generate Ideas	3. Determine PreliminaryProblem	3. Present Cover Story
4. Present Multiple Perspectives	4. Define and Assign Roles	4. Establish Roles
5. Research and Revise	5. Engage in Problem Solving	5. Operate Sceranios
6. Test your Mettle	6. Finalise Solution	6. Provide Resources
7. Go Public	7. Synthesize and Reflect	7. Provide Feedback
8. Progressive Deepening	8. Assess Products and Processes	
9. Reflection and Decision Assessment	9. Provide Closure	
5E Instructional Model (BSCS, 2006)	**Problem-Based Learning** (Barrows, 1985)	**Case-Based Reasoning** (Aamodt & Plaza, 1994)
1. Engage	1. Start NewClass	1.Present New Case/Problem
2. Explore	2. Start New Problem	2. Retrieve Similar Cases
3. Explain	3. Problem Follow-Up	3. Reuse Information
4. Elaborate	4. Performance Presentations	4. Revise Proposed Solution
5. Evaluate	5. After Conclusion of Problem	5. Retain Useful Experiences
Experiential Learning (Pfeiffer & Jones, 1975)	**Simulation Model** (Joyce, Weil, & Showers, 1992)	**Constructivist Learning** (Jonassen, 1999)
1. Experience	1. Orientation	1. Select Problem
2. Publish	2. Participant Training	2. Provide Related Cases
3. Process	3. Simulation Operations	3. Provide Information
4. Internalize	4. Participant Debriefing	4. Provide Cognitive Tools
5. Generalize	5. Appraise and redesign the simulation	5. Provide Conversation Tools
6. Apply		6. Provide Social Support

5.5. Game design – educational aims and objectives

The outcomes of literature review on Game design and applied pedagogy were used to inform the design of GBL in Mechanical engineering.

The stages of Instructional Design were addressed (Gagné, (1992), Jonassen (1999), Nelson (1999), Schank et al., (1999), Stapleton and Hughes (2006), Becker, (2007)) although not all in a formal manner – there was not a formal pitch nor game concept documents even though these issues were addressed, be it in informal manner. So as an example of applying Instructional Design to practice whilst complying to the theory the researcher addressed, Why? How? And What? (Stapleton and Hughes (2006)-see section 5.4).

The intention was to arrive at a proposal that addressed the learning outcomes and evaluate after the event. A readily available prototype was used (the resin puzzle) as supplied by Protomold (www.protomold.eu/parts). This was identified as an ideally suitable artefact that met the requirements for the experimental event but could also be evaluated in terms of suitability in developing the gamification event further.

The game consists of a nine-part Resin Puzzle Key. Figure 5.1 shows the nine parts of the puzzle and figure 5.2 shows the assembled puzzle. Each piece of the puzzle is made from a different polymer type and is colour coded accordingly. Each of polymers is more suited to certain design applications and one of the objectives of the game is for students to investigate material application and retain the information for questions addressed by the facilitator (cognitive recollection). Although the artefact first appears simple, in a situated educational game environment it can offer a challenging activity.

Learners were provided with instructions regarding the aims and objectives of the activity, the rules of the game and how it was to be conducted. Communication of the instructional approach would also assist in the future design and development of the gamification process. Learners were briefed on defined goals, learning objectives, operational instructions and rules of the game. They were thus able to gauge their own progress during the game.

Students should be paired within a class size of no more than 30 (15 maximum competing pairs) for the activity. The typical size was closer to half that. There were a total of six groups partaking in the game at different times during the period of a week. It is important to note here that students could not access the model files or the resin puzzle game outside the scheduled sessions. The first objective is to solve the puzzle in their allocated pairs by assembling the pieces following basic graphical instruction (Collaborative Problem Solving – Nelson, 1999). Graphical guidance to solving the puzzles is only provided following a lapse of time (15 minutes) in which to complete it. It is unusual for students to be able to solve the puzzle without basic illustrative guidance, yet a small number had achieved this showing good aptitude for practical and logical problem solving.

Students will be advised to remember the material of each piece of the puzzle and the associated colour. The colours help them to form a mental link to the type of polymer for investigation.

Learners will be observed as to how they are collaborating to solve the puzzle and timed accordingly. A display board will record the ranking order of completers and will score them according to their order of completing the puzzle. Extra points will be awarded for each repeated completed assembly, until time is called. The first part of the game is run for 40 minutes.

The next part of the game entails a virtual assembly of the puzzle using a 3D Computer Aided Design (CAD) Solid Modelling system. This part of the game is also time constrained. Students will be given access to the 3D Solid models of the individual puzzle parts to form a virtual assembly. This part of the game emulates the physical assembly completed prior but this time there will be no diagrammatic instructions as to how the parts are assembled and constrained. This should be completed based on memory (Learning by Doing – Schank, Berman & Macpherson, 1999) and will highlight retention from the previous part of the game. In order to successfully complete this stage of the game students were required to draw on previous knowledge on SolidWorks assembly gained during the weeks leading to gaming activity. They were required to apply virtual manipulation skills and constrain the individual modelled pieces by judgement, visualisation, planning and methodical thinking Anderson, (2002). The range of ‘mate’ constraints required was not exhaustive as this would have distracted some students from the overall objectives of the game. Constraints such ‘coincident’ mate and ‘width’ mate in addition to part rotation for orientation would suffice for completing the virtual assembly. The build process would prove to be significantly easier provided that the pieces were assembled in a particular order which could be established during the physical build (Chickering, (1977), Linn, (2000), Beaty, (2003)). The most successful students had already identified this before they arrived at the virtual build stage.

Figure 5.1: The nine parts of the Resin Puzzle Key

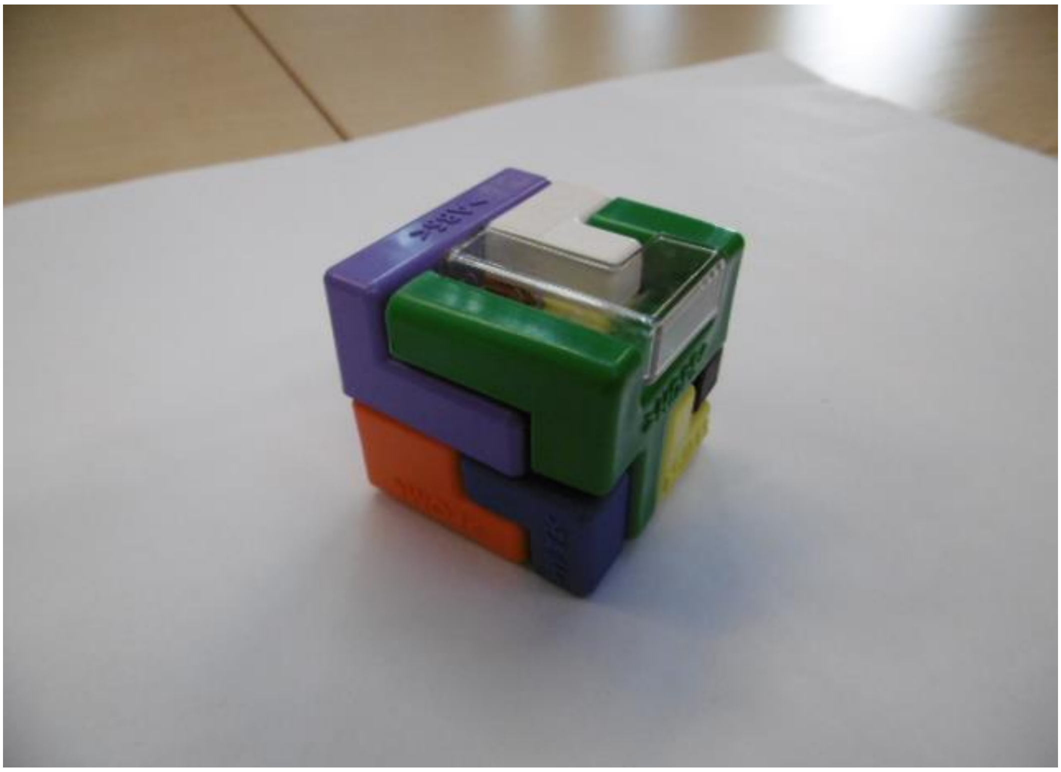


Figure 5.2: The assembled Resin Puzzle Key

5.6. Learning pre-requisites

Proficiency in the use of the 3D CAD modelling software, SolidWorks for assembly, is achieved through instruction and practice during the weeks prior to the activity using a range of different assemblies. Each student pair is required to contribute to the assembly build. Participants are observed while doing so. This helps resolve potential unfair advantage of having a particularly strong individual member in a pair working solo to complete the entire exercise. Collaboration is possible through partnership between pairs, providing a tool for conversation (Constructivist Learning and collaboration, Jonassen, (1999) and Nelson, (1999)). As in the previous part of the game, a display board will be used to record the ranking order of completers and are scored accordingly.

Students are also expected to have the pre-requisite skills of searching for the information required in the quiz on materials properties for the plastics. Knowledge and recollection is not as important as the ability to source information. The important aspect of this part of the overall activity is to raise awareness of the availability of a range of engineering polymers available to engineering designers.

5.7. Research questions and outcomes

There were several questions that were posed during the development of the learning game activity. Guidelines for good practice in GBL were followed. The research questions to be addressed became more focussed, compared to those listed in section 5.2 and were aimed at establishing the following:

- Had the students applied the skills and knowledge gained in the sessions leading to the event and were skills further reinforced, partly through collaborative learning with their assigned partner during the activity?
- Which students had performed better and why? Is there a link to prior learning, attendance and qualifications at point of entry in to Higher Education?
- Had collaboration enhanced or hindered certain competitors and why?

- Did the activity serve as an effective means of formative self-assessment, to gauge standards of students against peers?
- Was the activity enjoyable as an alternative method of delivery?
- Would the activity lead to improved performance in assessment?
- Was there a link between performance in manual and computer assembly?

5.8. Game based activity deployment

The attendance for all the students during the weeks leading to the activity was recorded. We can therefore relate performance to attendance as one factor in the research.

Each student had registered their presence and participation prior to the game. We considered this to be important in order to accurately monitor groups and the profile of participants. To have failed to maintain an accurate record of this, would have skewed the results of the experiment. The accurate tagging of participants was therefore important. Educational background information as well as recreational interests (which may have had relevance to chosen study at undergraduate level) for each participant was available on record.

Research results analysis was based on comparisons between participants (experimental group) and non-participants (control group). The division of the groups for the experiment was based on two academic years (2015/2016 and 2016/2017). The students who were enrolled for the same module during the previous year had not taken part in the game but were assessed in exactly the same way at the end of year (first control group). The assessment was based on successful completion and understanding of a set of assembly exercises. Both the control groups and the experimental group had the same exercises to complete and assessed in exactly the same way. This was one-to-one questioning on assembly constraints based on the given exercises. An example of one of the exercises on which students were assessed at the end of year is shown in figure 5.3. As in similar examples students are individually questioned on applied constraints, editing individual parts for improved fit, limiting the range of movement of specific parts etc. The experiment was to establish whether the opportunity to reinforce key skills during the GBL event would allow the experimental group to score higher in assessment, given that both the control and experimental groups had identical assessed work.

The absent or non-participating students in the gaming event was identified as being mostly incidental (non-intentional) as was also the absence of part of the control group cohort. Identified reasons included illness, parental family home visits and part-time work commitments.

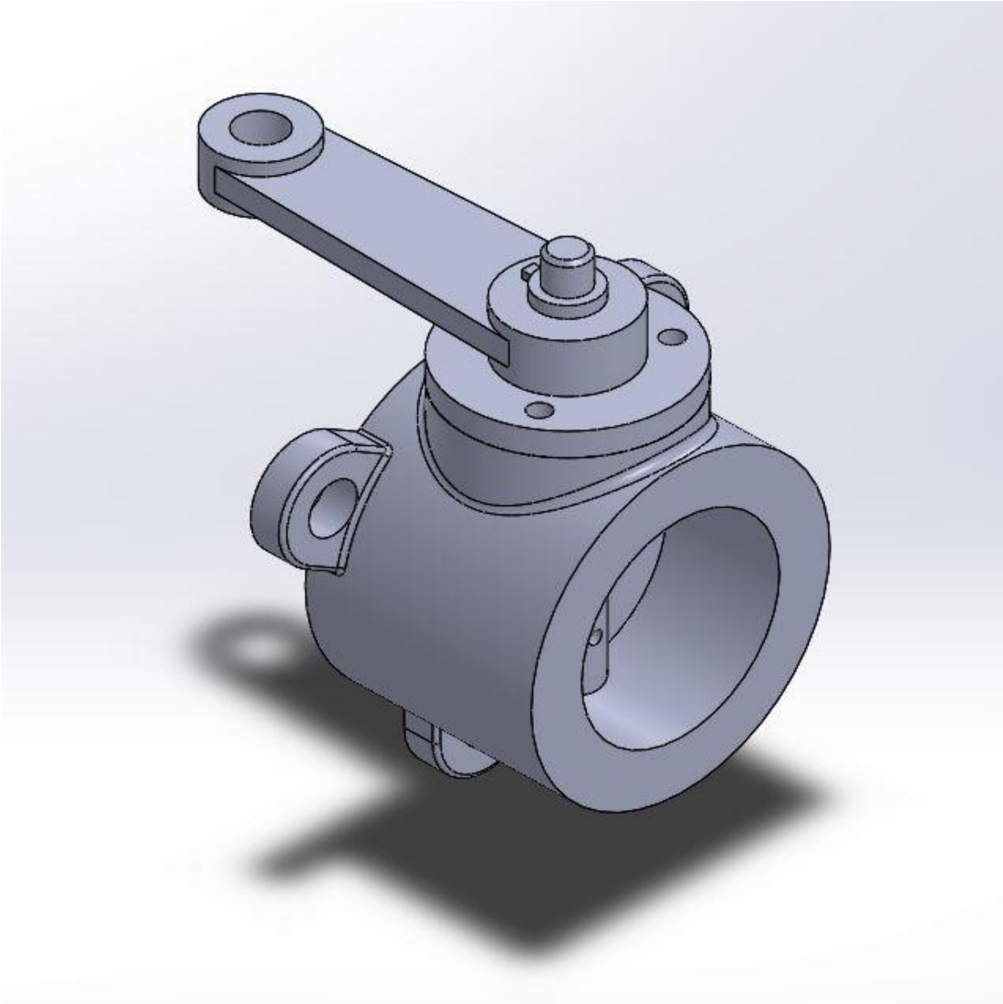


Figure 5.3: One of several assembly exercises used to assess students in their assembly skills and knowledge, at the end of the year

The game was conducted as part of the timetabled practical computer laboratory based sessions. Six groups of students took part in the GBL activity. The average size of the group was 15. The game was conducted as designed and under close supervision in order to ensure that rules and guidelines were adhered to. Both hands-on and simulated computer-based activities of the game were performed. The students were rewarded in accordance to their ranking position.

On presentation of the overall results in performance and allocation of prizes for the three top finishers, participants were given a questionnaire to complete and return. The questions were intended to establish whether certain research questions and objectives were addressed in running the event. The questions therefore addressed aspects such as fun, collaboration, self-assessment in performance, absorbency during the tasks, learning by doing etc. The results from more than fifty questionnaires were to provide qualitative feedback and results.

Quantitative results could therefore be established through records and monitoring performance at a later date, post gaming event. The use of this information was used as indicated in Chart 11 (figure 5.14). This Chart tracks the tariff points at entry to HE for both control and experimental groups and indicates differences in performance, with and without exposure to the gaming event. The researchers were also interested in the type of educational background in which the tariff points were earned (National Vocational Qualifications or General Certificate of Secondary Education qualifications). This is further discussed under sections 5.11 and 5.12 where the research questions are addressed.

5.9. Summary of findings, analysis and conclusions from feedback questionnaires

A total of 55 questionnaires were returned by students that participated in the experimental assembly game. This was a good response rate which could later allow comparison with the control group, who did not participate. The purpose of the questionnaire was to determine the effectiveness of the gamification event, as perceived by the students and to verify this as part of on-going research. At the core of the questionnaire were questions intended to establish whether the activity had met with Gagné’s defined nine elements of instruction (Gagné, Briggs & Wagner, 1992) which serve as a useful guide to game design and instructional design, to this day. The nine events are as listed in table 5.3 below. These are also as discussed and applied by Becker K, (2006 and Becker K 2010).

Table 5.3: a list of Gagné's nine events interpreted through game design

1. Gaining Attention (Reception)	Informing learners of the proposed gaming activity with element of competition amongst peers
2. Informing Learners of the Objective (Expectancy)	To have sufficient proficiency to enable them to participate with a certain degree of competitiveness
3. Stimulation Recall of Prior Learning (Retrieval)	Applying what has been covered in practical CAD session
4. Presenting the Stimulus (Selective Perception)	The physical artefact used which forms a puzzle
5. Providing Learning Guidance (Semantic Encoding)	Making the connection between physical artefact and virtual build
6. Eliciting Performance (Responding)	Observing performance compared to peers in real time
7. Providing Feedback (Reinforcement)	Repeating the exercise to achieve greater proficiency in build-both physical and virtual
8. Assessing Performance (Retrieval)	How did I do compared to my peers-overall position
9. Enhancing Retention and Transfer (Generalization)	Better informed on self-proficiency prior to assessment

The nine events can be embodied, directly or indirectly, to game elements. They are widely used as a benchmark for evaluating educational games (Becker K. 2006).

Once the responses are analysed, comments and conclusions for future will be made that will assist in improvements in the development of future work.

Essential elements of educational gaming must include fun and engagement by the learner and these can be in jeopardy if designed by the educator alone without reference to them. According to Hirumi and Stapleton (2010), games that over-emphasize educational requirements often fall short of realising the potential of play, game and story for creating memorable experiences.

5.10. Responses to activity questionnaire

Question 1 (see figure 5.4, Chart 1) addressed the matter of whether participants had thought that they had applied skills and knowledge gained during the weeks leading to the game and whether the skills were further enforced during the activity. A statement was given to determine whether they agreed or disagreed along with the option of commenting. Comments were of value to the authors as they provided a valuable means of described views from the participants. Of the 55 returned questionnaires, 96% of respondents agreed that they had applied skills and knowledge that was further underpinned, whilst 4% disagreed. Most comments had indicated that the anticipation of the event had incentivised preparation by practice, something that wouldn't otherwise had normally been done (except perhaps in preparation for an examination as opposed to a gaming event). One able student considered the event to have become tedious after a while, something that wasn't reflected in the comments of others. This would indicate that the event utilised skills at a level that was within the proficiency of most.

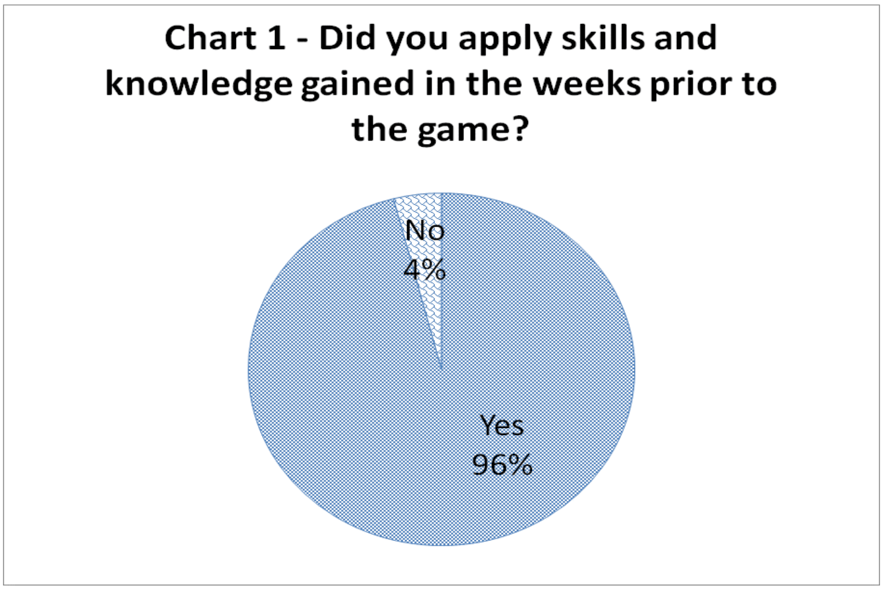


Figure 5.4: Chart 1 - Addresses the question as to whether participants had thought that they had applied skills and knowledge gained during the weeks leading to the game and whether the skills were further enforced during the activity

Question 2 (figure 5.5, Chart 2) was intended at establishing whether the game was fun to participate in whilst simultaneously offering an element of competition against peers within an Activity Based Learning environment. The researcher's aim was to create a fun activity in accordance to theory of fun and intrinsic motivation. Fun is associated with play and is considered to be the optimal life experience which triggers the flow phenomenon (Csikszentmihalyi, 1990, 1996) and is most aligned with theories of intrinsic motivation (Deci & Ryan, 1985; Lepper, Keavney & Drake, 1996). Flow theory is defined by Csikszentmihalyi as an optimal life experience in which people are so absorbed and engaged by the experience of activity that time appears to diminish or vanish. In adults this typically reported whilst experiencing leisure related activities such as gardening or woodworking (though any activity can produce it). Flow theory includes the following components:

- Optimal challenge
- Completely attention absorbing
- Contains clear goals and provides clear feedback on whether the goals are being met
- Sufficiently absorbing to free the participant of other worries
- Feelings of self-consciousness are alleviated
- Total control in the activity
- Time does not seem to exist.

Engineering is a vocational subject typically studied by learners who are practical problem solvers. There is therefore a strong case for a significant proportion of learning activities in encompass flow theory (Gupta S Madhu, 2008 and Euchner, J 2014). 98% of respondents agreed that it was whilst only 2% disagreed. It is anticipated that few respondents who disagreed were the least prepared. General comments included 'enjoyable' whilst also 'very competitive'.

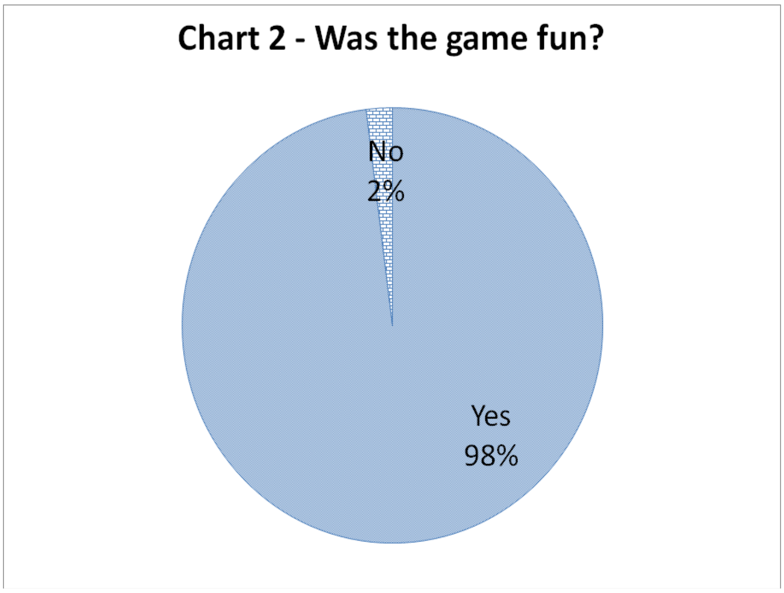


Figure 5.5: Chart 2 - Did learners consider the activity fun?

Question 3 (see figure 5.6, Chart 3) focused on the collaborative aspects of learning and whether it had helped participants in the activity. Pairing of participants was a random process rather than matching by set criteria. This was intentional in order to establish the response to this. Collaboration was required for both mechanical and physical assembly using a mix of verbal communication as well as practical skills (by applying logic and psychomotor ability). It was regarded as an important aspect of the game (Romero M, 2012, Nelson, 1999) along with the social aspect. Collaboration also fostered a situated learning by doing approach (Van Eck R, 2006). 95% of respondents had agreed that collaboration was applied but the extent differed when compared to competing teams. 5% disagreed in that they considered collaboration to have been ineffective. The key reasons that were identified were due to:

> ‘Lack of contribution by partner due to variability in ability’.
>
> Most comments regarding collaboration were positive:
>
> ‘Communicated well’
>
> ‘If the task was known in advance we would have communicated a better strategy for solving the puzzle’
>
> ‘good game for teamwork’ and
>
> ‘we communicated and adapted our solving technique for the challenge’.

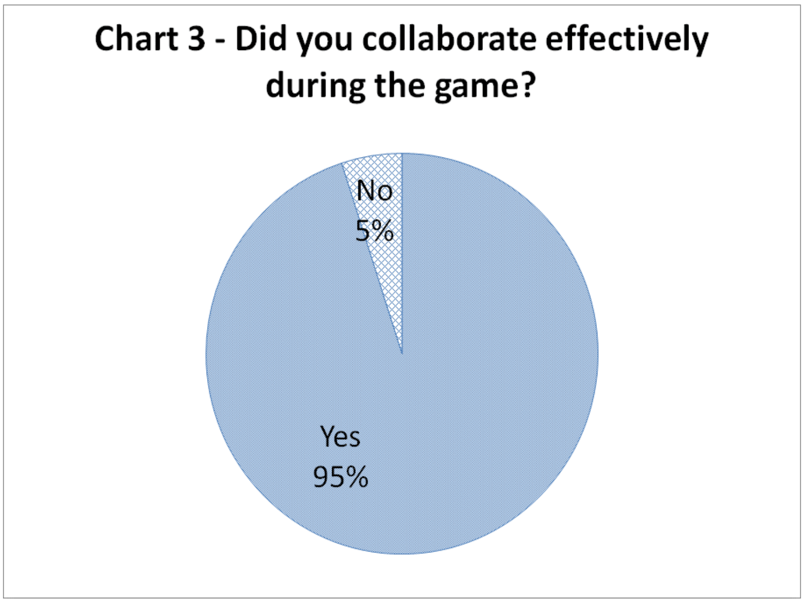


Figure 5.6: Chart 3 - Refers to collaboration between learners

Question 4 (see figure 5.7, Chart 4) was intended to establish the proportion of participants that had considered the gaming event as an opportunity to gauge their own standard against that of their peers, thus providing a means of formative self-assessment. Although 87% agreed that it had, 13% disagreed and claimed that it had not. This was anticipated as performance was often governed by how well standards of pairs were matched (an aspect that was left to chance, deliberately, so that weaker students could be assisted by their peer).

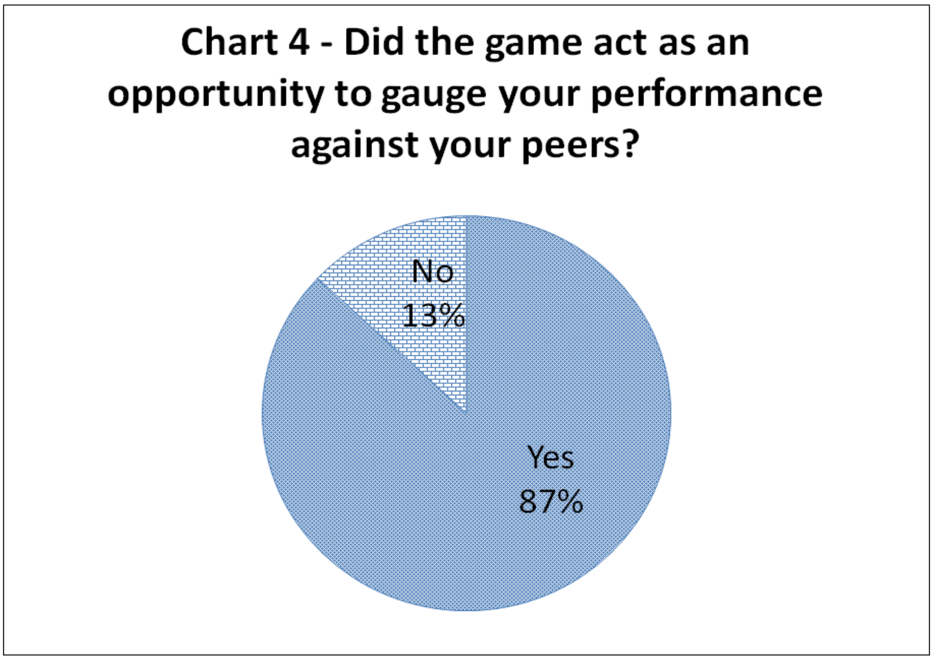


Figure 5.7: Chart 4 - Refers to the response to the question regarding gauging performance against that of peers

Question 5 (see figure 5.8, Chart 5) required feedback for establishing whether the activity was a welcome change to the usual and 'traditional' CAD practical sessions. 95% agreed that it was and feedback comments indicate a strong agreement with this. Words used to respond to this question included:

> 'Great hands-on learning', 'fun and different', 'A good occasional alternative', 'different and interesting', 'engaging', 'much more fan than usual lesson', 'nice change from usual and the music helped', 'fun at start gradually becoming more challenging', 'more sessions like this…. appreciated'

Only 5% did not consider the event to be a refreshing change and gave no comment of note. This may have indicated that they did not have a strong enough opinion.

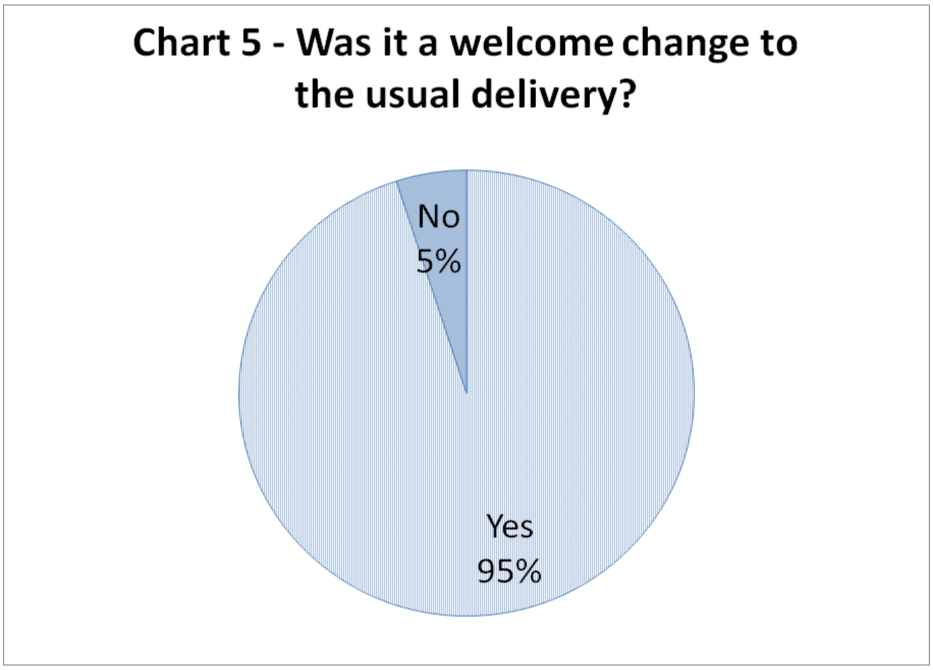


Figure 5.8: Chart 5 - Was the activity a welcome change?

Question 6 (see figure 5.9, Chart 6) was intended to establish whether students considered whether the physical build that preceded the CAD build had made the CAD build process easier. As was anticipated, unless the participant already had sufficient proficiency in using the software, the mechanical build was of little help. 62% of respondents said that it helped but the comments clarified the justification for the responses. 5% disagreed in that they did not think that the mechanical build had helped and 33% said it partly helped. Where the mechanical build had helped was in the association of colour with each piece and order of sequence and position in the build. The colours and physical pieces therefore appeared to have helped more than hindered in establishing a logical building process and memorizing the process with aid of the colours.

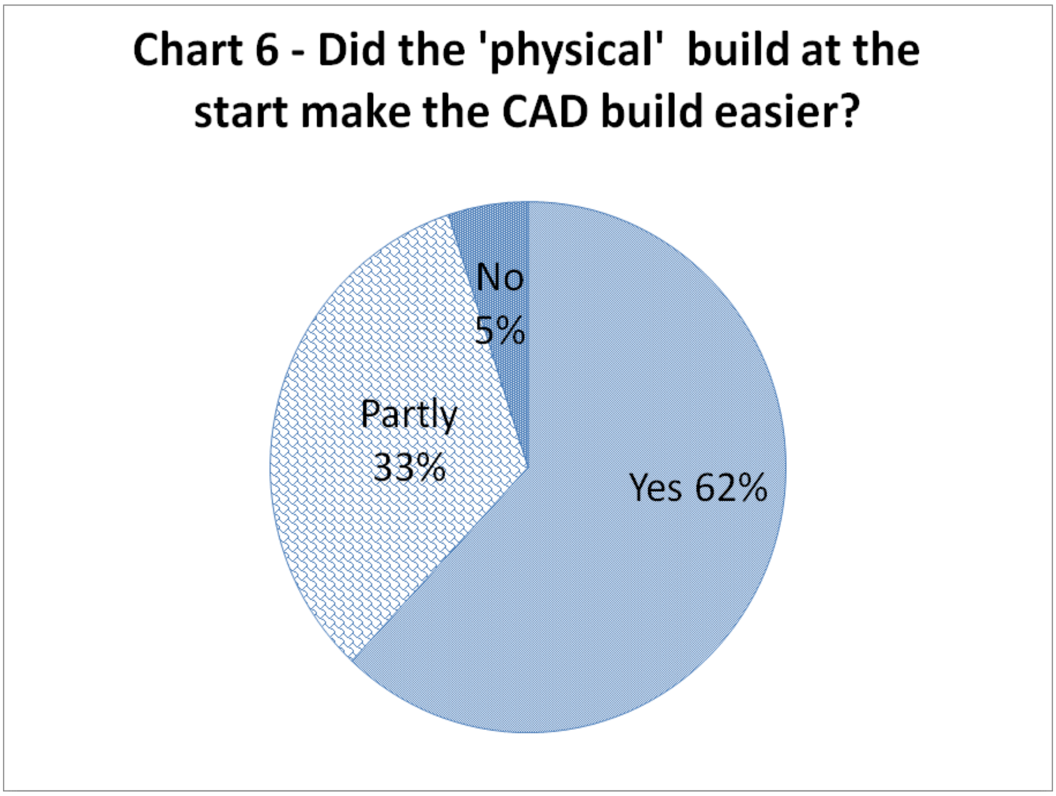


Figure 5.9: Chart 6 - Refers to the question that links the physical build to the virtual build

Question 7 (see figure 5.10, Chart 7) required feedback on collaborative working with a peer. As collaborative pairs were selected at random, effective collaboration depended on how well balanced in proficiency and aptitude the pair were. In cases where there was an imbalance it was expected that the stronger member would take the lead and the weaker member would benefit by learning from the stronger member. Although this was often the case, there was also the risk of resentment due to weakening the team and scoring lower in the overall rankings. 60% had claimed that it was helpful working with a peer (though a proportion of these respondents may have come from the weaker member who benefitted from working with a more able and proficient partner). 18% had responded negatively to claim that it was not helpful to them having a partner for the activity and 22% claimed that it was only partly helpful. The response score may indicate to us that weaker learners had benefited from co-working and had responded positively. The more proficient students who were partnered with a weaker member may have responded negatively or to this question. Well matched pairs who collaborated well would also have answered positively.

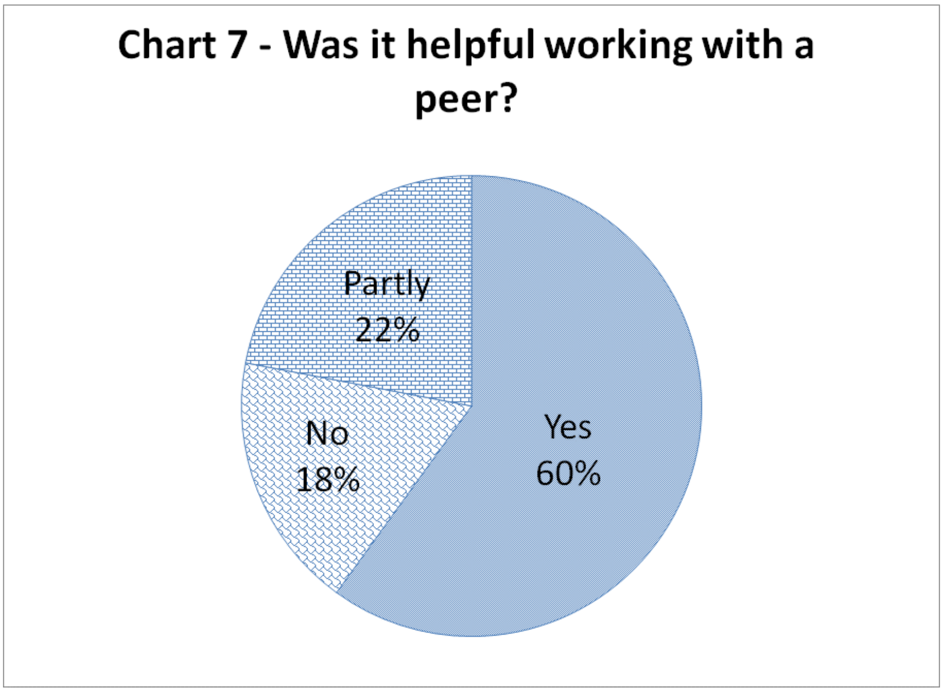


Figure 5.10: Chart 7 - Did collaboration help?

Question 8 (see figure 5.11, Chart 8) asked participants whether, in their opinion, there should be more activity based learning sessions during class. 87% of respondents responded positively with 'YES', 9% said 'NO' and 4% were indifferent. The consensus was therefore in favour of more ABL.

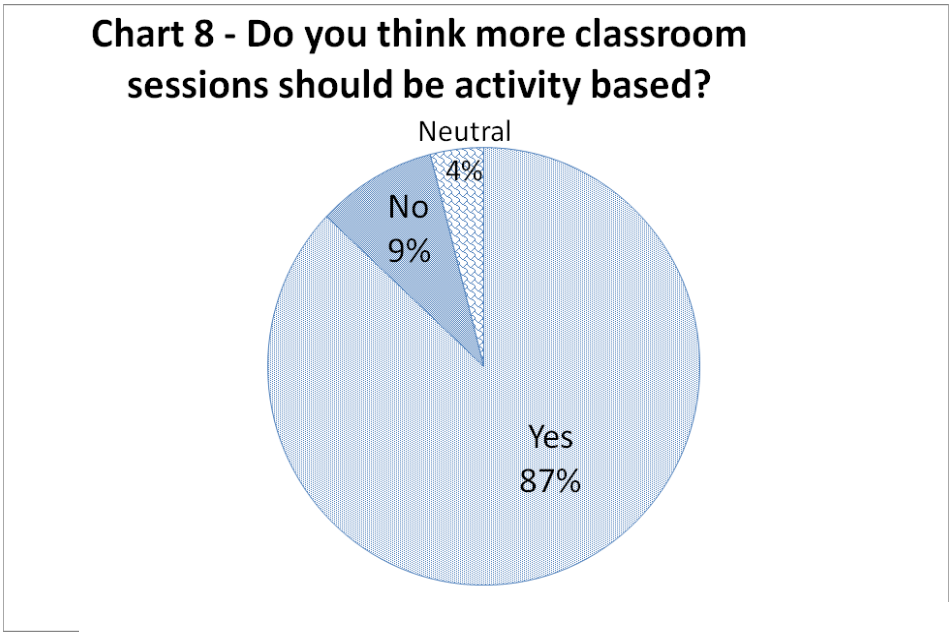


Figure 5.11: Chart 8 - Should more classroom session be like this?

Question 9 (see figure 5.12, Chart 9) asked whether the activity helped develop skills in the software. The anticipated response was that it would not as that was not an objective of the activity. To reinforce existing knowledge, raise self-awareness in proficiency and have fun in the process were part of the objective, yet 64% of respondents thought that the activity had helped them develop, 35% did not and 1% was indifferent.

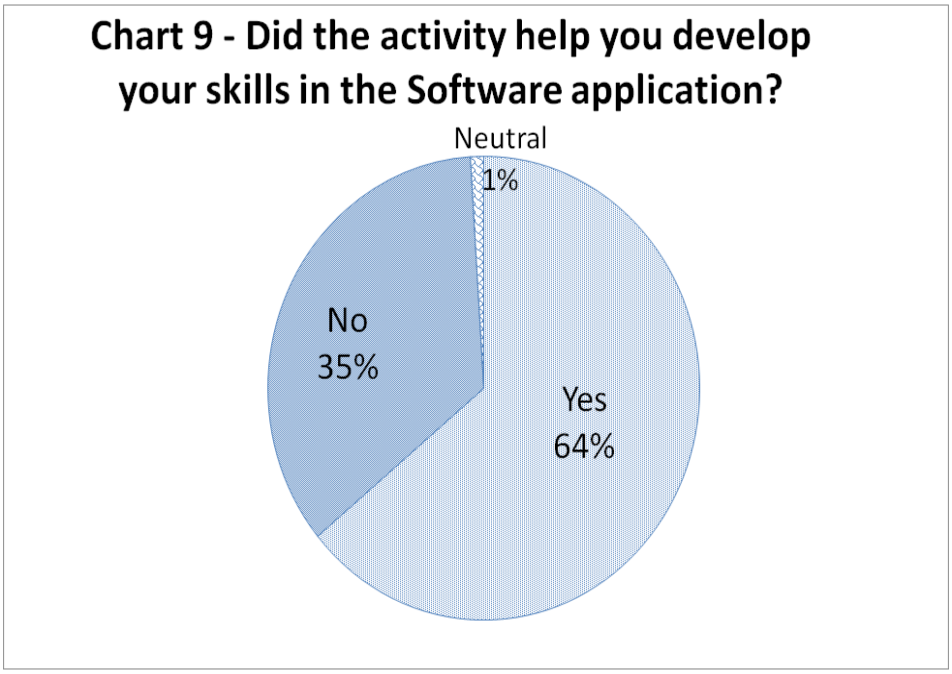


Figure 5.12: Chart 9 - Did the activity help develop skills?

Question 10 (see, figure 5.13, Chart 10) sought to establish whether most students thought that the activity was interesting and relevant to their course. The majority (82%) thought that it was whilst 4% thought that it was not and 14% were indifferent.

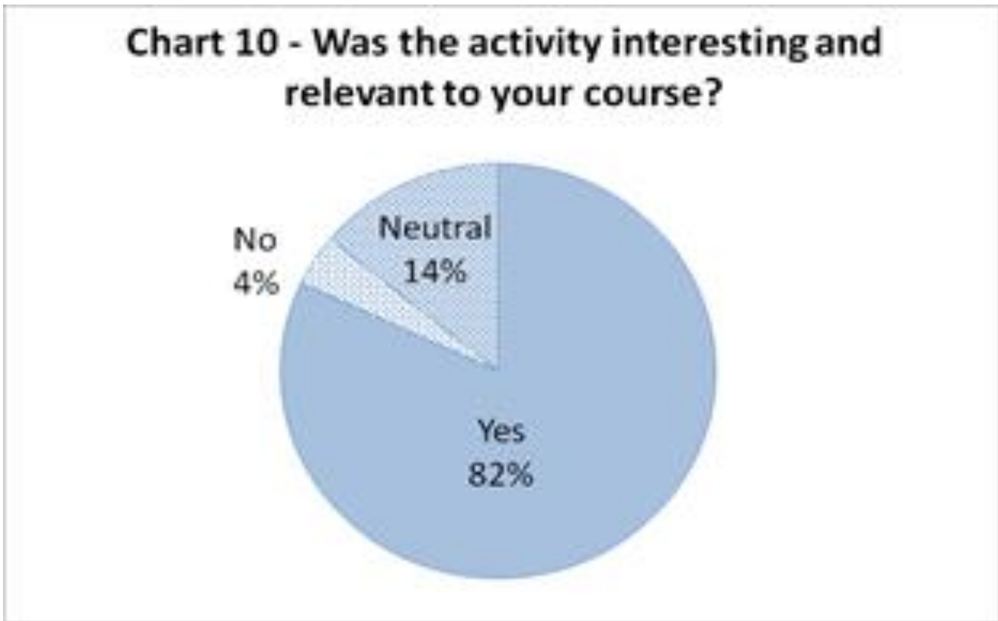


Figure 5.13: Chart 10 - Refers to the question of perception of activity and relevance to course

5.11. Addressing the research questions

The key questions to be addressed in this research are:

- ***Is there a correlation between the students who performed in the higher finishing positions at the end of the gamification event and their end of year assessment element in assembly?***

The higher finishing position students are classed as those who scored high enough to finish within a gold, silver or bronze position within each set of students. The game was repeated for a total of six sets of students (separate tutorial groups). 80 students had taken part in the game of which 37 had been classed in either a gold, silver or bronze finishing position. We are therefore able to compare the 37 top finishers with the remainder 43 who either completed but ranked below the top finishers of gold, silver or bronze or failed to complete altogether (as indicated by DNF on the score of results).

The 37 top classed finishers had achieved an overall score of 76.7% in the end of year assessment exercise. This compared to 74% for the lower ranking students, which is not significantly different.

- ***How did the 75 absent students perform in their end of year assessment element in assembly compared with the 80 students who took part in the gamification event?***

These 75 students are classed as one of control group in this research. We can determine whether, overall, they had performed better, worse or no different to the experimental group and to what extent. The other control group were the students of 2015/2016 who had not taken part in the game but assessed in exactly the same method at the end of year.

The students who did not take part in the game scored an average of 67.8% in the end of year assessment as compared to 74% for all game participants (6.2% average difference in assessment score)

- ***Did the students who performed in the higher finishing positions enter Higher Education with a greater number of tariff points compared to the lower finishing and non-completing students?***

We are able to track the entry qualifications of all the participating students and hence make a comparison of the tariff points at entry into Higher Education between the top and lower finishing students. Tariff points are associated with the level of qualification at entry. The higher the grades, say at GCSE (General Certificate of Secondary Education) Advanced Level subjects, the higher the tariff points. Most qualifications, including National GNVQ (General Non-Vocational Qualifications) have an associated tariff weighting. Some qualifications such the Access into Higher Education completing certificate and the School's own Engineering Foundation Course don't have associated tariff points. Such courses have been established to assist either mature students or students with qualification unrelated to Science and Engineering, in order to gain entry on to Science, Technology and Engineering degree courses. School Leaving Diplomas within an International market of undergraduate recruitment don't have tariff points associated with them. It is of interest to establish whether students with unquantified tariff points at entry to Higher Education performed better or worse within the main cohort.

The average tariff points at entry to Higher Education for the top classed finishers were 293 points whilst for the remainder participating students this was 272. The difference in tariff points is not significant when you consider a grade A at Advanced Level GCSE (General Certificate of Secondary Education) carries 120 tariff points.

- ***How did the year group perform in comparison to the previous year's group?***

As this was the first year that the gamification activity was introduced, we wish to establish whether the year group had overall performed better than that of the previous year. However, as the previous year's cohort had not been introduced to the gamification activity, we may consider them as another control group of greater size. We shall then be able to compare their end of year assessment score average in the element of assembly with that of the students who took part in the gaming activity. A comparison between the overall tariff points average at entry will also be necessary.

The average score in assessment for all game participants was 74% whilst for the same assessment, during the previous year, the average score was 67.8%. This indicates a marked improvement of 6.2%. Zero scores and non-submit (NS) students have been excluded in the calculation of scores. However, it was observed that in a cohort of 157 students during 15/16 there were 15 non-scoring, NS students, 4 more than for the same size year group during 16/17, when the gaming event was introduced as part of teaching and learning activities. This indicated a correlation between performances and participation in the game based activities and overall coursework attainment.

Impact on overall assignment score with reference to assembly game participation

The assembly element of assessment formed only a part of the overall assessment but as a result of its introduction the overall assessment score was raised from 61.5% in the previous year to 65.8%. The reduction in NS students was confined to the assembly element of assessment. Students in the previous year (15/16) had an overall higher average of tariff points at entry to HE (288 compared to 272 for the

16/17 cohort). Despite the lower entry level to HE, the students exposed to the gaming activity had scored better in assessment than the students in 16/17 game participation activity.

5.12. Entry tariff and performance

It was almost inevitable that the 37 top performing students (classed as gold, silver and bronze positions) would be the students with the largest average of tariff points at entry to HE. This was verified (293 compared to 272) even though not significant.

Our interest was in the tariff points of DNF (Did Not Finish) game participants. These were students who did not manage to complete the game in the allocated time. Half (50%) of these students did not have any tariff points at entry to HE as they were admitted on a 1-year Foundation Course prior to undergraduate studies. The remainder 50% had entered HE with 205 tariff points which was significantly lower than (by 30%) as compared to the 37 top performing students.

We were also interested in the range of entry qualifications that attributed to the tariff points of the top performing students for this particular year group. These were primarily made up by GCE A'levels and Engineering specific level 3 qualifications (what are commonly known in the UK as BTEC awards-awarded by the Business and Technology Education Council). The lower performing students had a mixture of level 3 subjects but not engineering specific (such as Information and Communication Technologies (ICT) or Applied Sciences), foundation studies or a Certificate in Higher Education (CHE). The CHE is awarded on the basis of completing part of course at another HE. This would imply that the less performing students had set out in embarking on an engineering undergraduate course without the same conviction and focus as the better performing students. Improvement in performance was however achieved by introduction to the gaming activity in teaching and learning for all students.

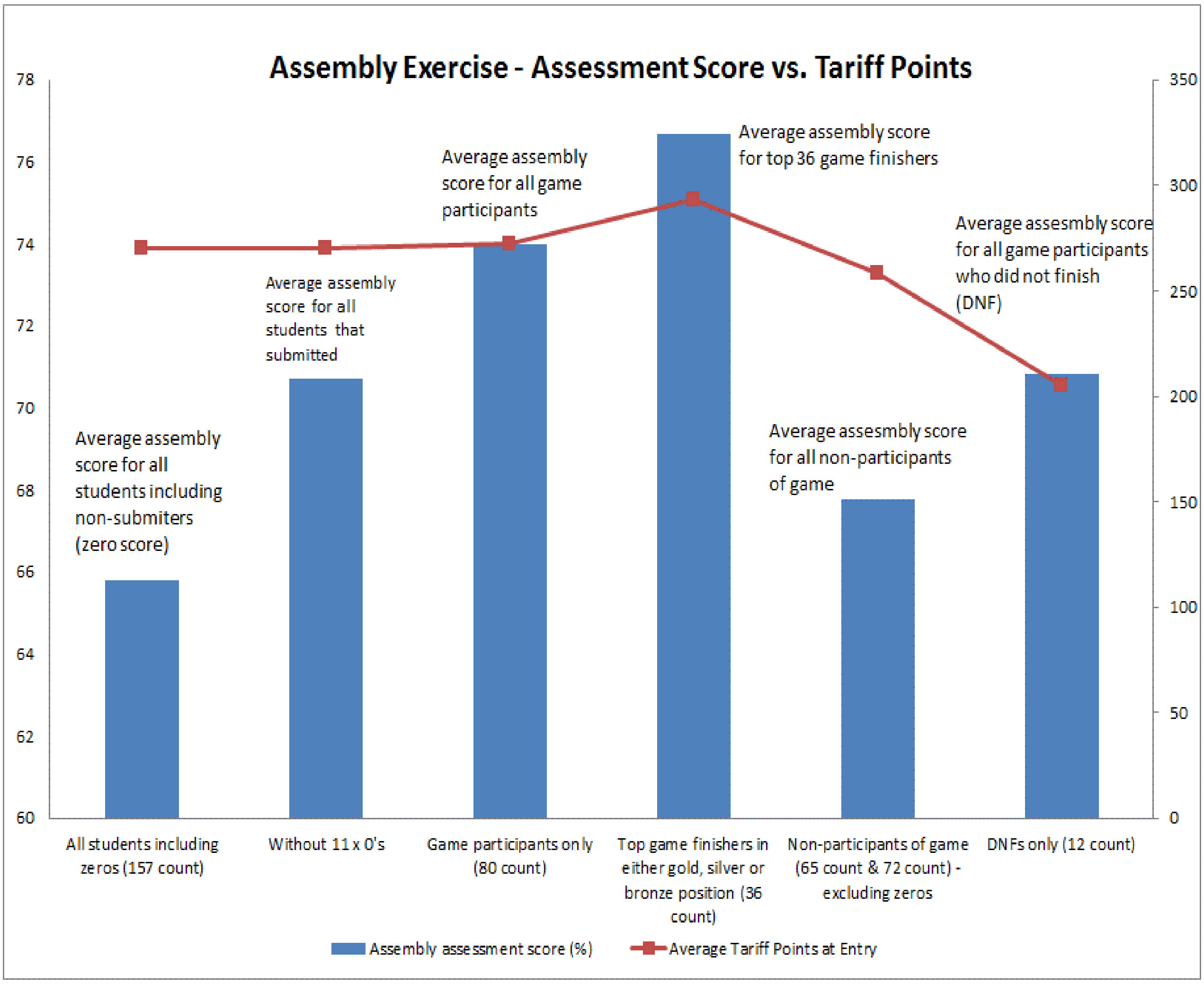


Figure 5.14: Chart 11 - Graphical representation of results showing improved overall performance by game participants and the student profiles in average tariff points at entry in to Higher Education. The red line represents the tariff points at entry of classified

5.13. Summary of case example

In this GBL case study we sought to determine how successful such an activity could be as part of mechanical engineering CAD education. We benchmarked the gaming against Gagné's defined nine elements of instruction (Gagné, Briggs & Wagner, 1992). The nine events were listed in table 10.

The qualitative results were overall very positive as is indicated from student feedback and reported in the Charts (1 to 10) along with the discussion accompanying these Charts.

The quantitative benefits of the activity overwhelmingly support further activity based learning (ABL) and, in particular, gamification (GBL) events in the teaching and learning process. Testimony to this are the results illustrated in figure 5.14, Chart 11, which show overall improvement in assessment results regardless of student academic level of achievement, as quantified in tariff points, at the point of entry into Higher Education.

5.14. Further work appended to the case study

Following the successful execution and outcome of case study 2, as detailed in this chapter, it had emerged from student feedback that they desired similar Activity Based Learning sessions but to incorporate actual mechanical parts or assembly of parts that they were able to relate to and learn from. So even though learners had benefitted from the activity whilst also experiencing an enjoyable learning activity, a desire for further collaborative learning activities was expressed. This subsequently led to an activity where students collaboratively reverse engineer a mechanical assembly, within CAD/CAM practical sessions. Figure 5.15 illustrates a single cylinder air engine, powered by compressed air. It consists of at least eleven parts which have been supplied to students in the form of 3D Solid models and were later given access to the physical true assembly, to explore within the class session.

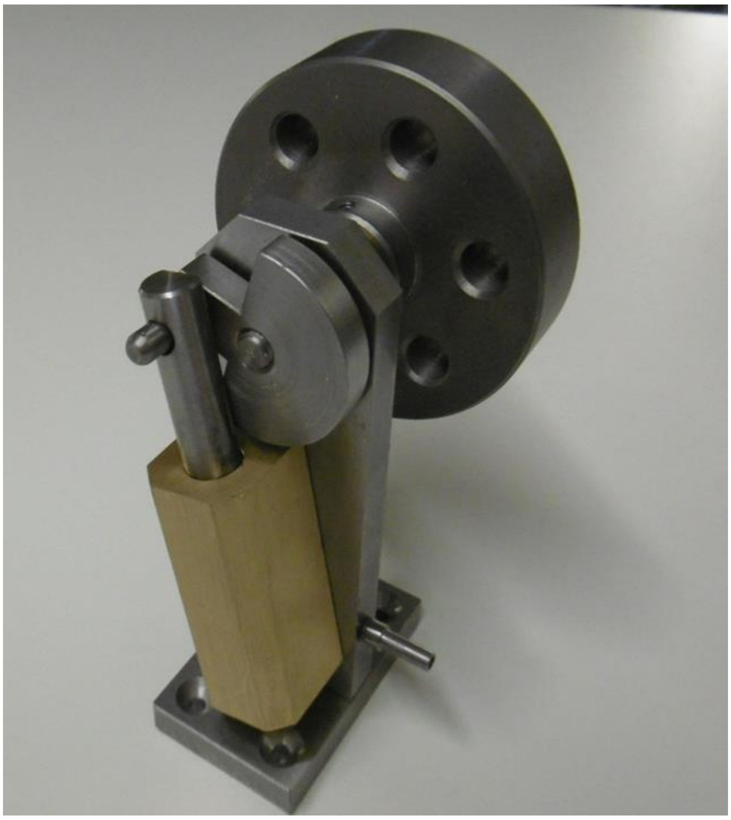


Figure 5.15: The single cylinder air engine used as a simple example for collaborative learning to reinforce principles of mechanical design

5.14.1. Activity deployment

The activity combines a number of educational pedagogical frameworks in that it presents learners with several active learning challenges. The initial problem was to determine how the virtual parts assemble without initially seeing the physical completed assembly. The random order of the 3D CAD modelled parts, are shown in figure 5.16. To do this, students have to determine the mechanical working of the device and construct an assembly based on existing 3D CAD knowledge to form a virtual assembly. The first part of the problem is time limited and once a certain period had lapsed, the physical assembly is revealed (we had several copies of the same physical assembly to use). The time allowed before the physical artefact was revealed for exploration depended on the overall progress of the group. Six groups had participated of approximately twenty-five students in each group. Abilities varied between groups. The first part is completed individually. This is because the 3D CAD knowledge required to complete the first part was covered in prior CAD practical sessions within the same module. The working of the assembly of parts as a complete mechanical working device was an individual challenge. This provides some indication to the facilitator as to mechanical aptitude, awareness and intuition of individual learners. The remainder of the activity is completed collaboratively, in pairs, during which learners produce detailed production drawings of each assembled part. To complete this task correctly they must consider surface finish, material specification and tolerances for specific fit between assembled parts.

Detailed drawings are then scored in accordance to how comprehensively they have been completed and participants are provided with formative feedback on their work.

Sets of drawings for a complete air engine were exchanged between peers who would score the drawings according to guidelines given by the tutor. Complete production level integrity of the drawings was required such that they could be supplied to a workshop for production, if necessary. Examples of the type of drawings that were required and produced are as shown in figures 5-17. Although this activity was not classed as a game (given previous criteria), it offered a great opportunity for ABL in which students worked and learned collaboratively.

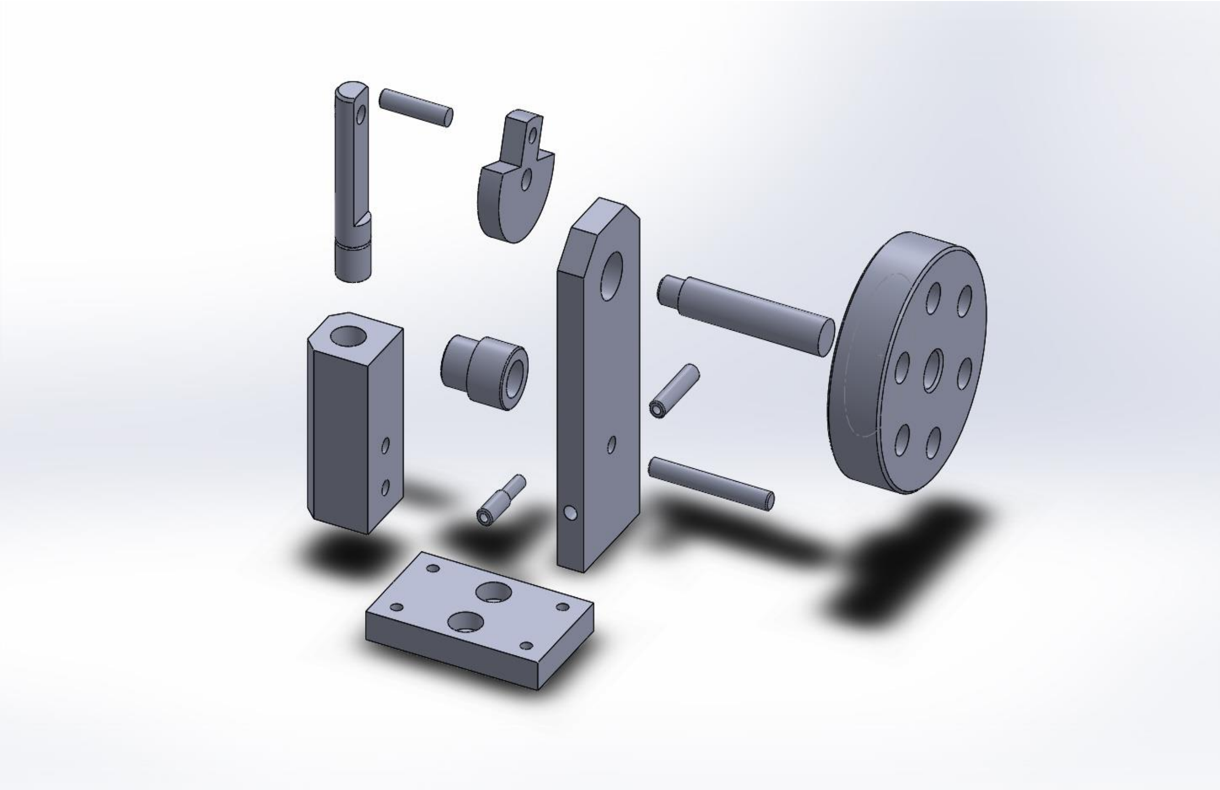
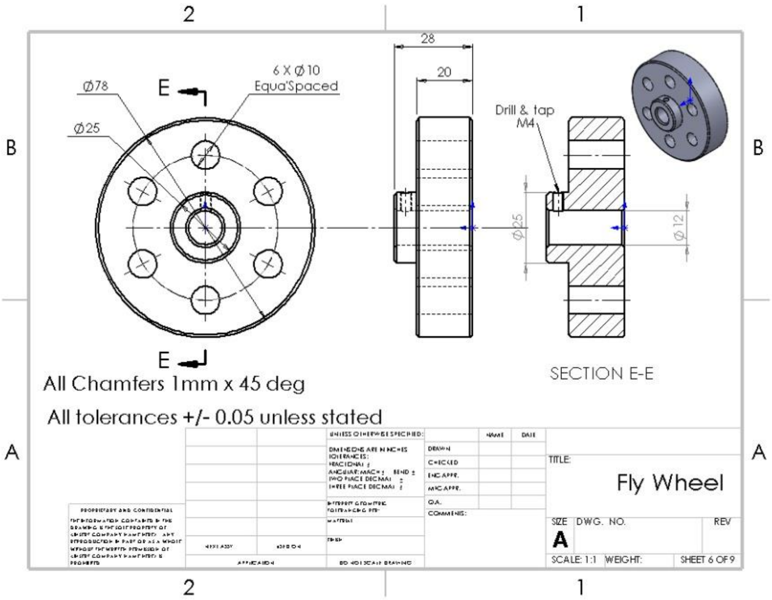


Figure 5.16: Learners are provided with the 3D modelled parts to build the air engine in a random order. They are then tasked to individually assemble the engine by first determining the method of operation hence the function of each part. Standard missing parts such as a spring and fasteners are required to be either modelled or retrieved (from a library). This forms part of the exercise



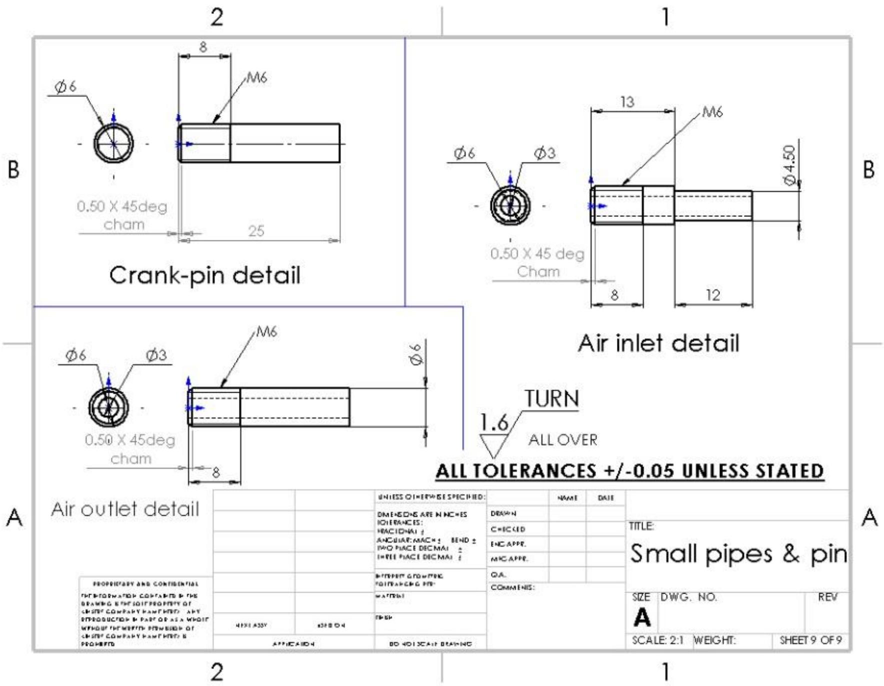


Figure 5.17: Examples of detailed parts drawing required to be produced by students collaboratively. Drawing were then peer assessed under tutor supervision

5.14.2. Learning pre-requisites

The subject matter that was associated with surface finish, materials selection and particularly tolerances were all covered earlier as part of other year 1 and 2 modules. Surface finish definition was covered as part of a mechanical design module and reiterated as part of this activity. With some exceptions, students, in general, do not attend all their timetabled sessions, so there was the possibility that some would have missed sessions on say, quantifying and defining surface finish or defining appropriate tolerances (limits and fits). The collaboration gave yet another opportunity for them to learn from each other as well as reinforce ground that had already been covered. This demonstrates an example of Concurrent and Integrated Engineering Education (CIEE) in which several parts of a curriculum are integrated as part of a single activity in which learners can put knowledge into context.

5.14.3. Activity design – educational aims and objectives

The outcomes of the literature review in chapter 2 on Active learning and applied pedagogy were used to inform the design of the activity in Mechanical Engineering. Stages of Instructional Design were addressed and the educational aims and objectives were clear from the outset as these helped formulate the activity. Learners were made clear of the objectives of the exercise. The simple mechanical assembly was carefully chosen as it was not overtly complicated thus enabling the activity to be completed within two practical CAD sessions (three hours in total). The assembly was also suitable as it incorporated important elements of detail mechanical design such as surface finish, tolerances (limits and fits), process consideration related to surface finish and technical communication of certain features (such as dimensioning the holes on the flywheel).

5.14.4. Research questions and outcomes

As in the earlier part of the case study, there were several questions posed during the development of the learning game activity. Guidelines for good practice were followed and in accordance to previously reviewed work. The research questions to be addressed were aimed at establishing the following:

- Can we introduce active learning activities which are not of prolonged extension, hence manageable within the constraints of timetabled classes? And can such activities facilitate micro learning?

- Can we successfully introduce active learning that incorporates more than one educational pedagogical framework in that it presents learners with several active learning challenges? These could include Collaborative Learning and Problem Based Learning within a single activity with opportunity for formative feedback.
- Had the students applied knowledge and skills gained in:

  1. Prior sessions within the same module?

  2. Prior knowledge gained in other modules at different stages of their course?
- Was prior knowledge reinforced through the Activity which utilized a physical artefact example?
- Was the activity enjoyable as an alternative method of delivery?
- Had learners become more confident in application of the subject matter covered?
- Had collaboration with another person helped promote learning?

5.14.5. Responses to activity questionnaire – summary of findings

A questionnaire was given out in order to establish the students' perceived benefits in completing such an activity. A full copy of the questionnaire is included in appendix A. The questions are listed below. Nine responses were required in the form of either 'agree', 'disagree', 'unsure' along an invited optional comment. Two responses were required in the form of 'yes', 'no', with an optional comment. A breakdown of the responses is given in figure 5.18, Chart 12 and a discussion of the response scores follows.

1. I have previously covered tolerances and/or surface finish definition whilst either on this course or at another institution. *(Agree/Disagree/Comment)*
2. The exercise helped reinforce previously gained knowledge and/or provided me with new knowledge on tolerances and surface finish. *(Agree/Disagree/Comment)*

3. I now feel more confident that I can complete drawings for production whilst also defining dimensional tolerances and surface finish. *(Agree/Disagree/Comment)*

4. I collaborated effectively with a peer to dimension the components by checking each other's work and making corrections accordingly. *(Agree/Disagree/Comment)*

5. It was helpful to me when the tutor had gone through the recommended method for dimensioning and applying tolerances as it provided me with feedback on my work. *(Agree/Disagree/Comment)*

6. Overall, the activity was enjoyable and I would welcome more activities like it which use physical artefacts as a focus for the session. *(Agree/Disagree/Comment)*

7. My dimensioning skills using Solidworks have improved during the current academic year due to the practical work covered as part of this module in CAD/CAM. *(Agree/Disagree/Comment)*

8. I now feel more confident that I can apply tolerances using Solidworks to stipulate a type of fit (clearance or transitional) *(Agree/Disagree/Comment)*

9. I think that there is sufficient content on this module for Solidworks assembly and drawing/detailing. *(Agree/Disagree/Comment)*

10. Working with another person helped me in completing the exercise effectively. Was it helpful working with a peer? *(Yes/No/Partly/Comment)*

11. Do you think that the activity has helped you develop your skills in Solidworks further? *(Yes/No/Comment)*

The number of questionnaires returned was 33, which was disappointing. The results for which are presented below.

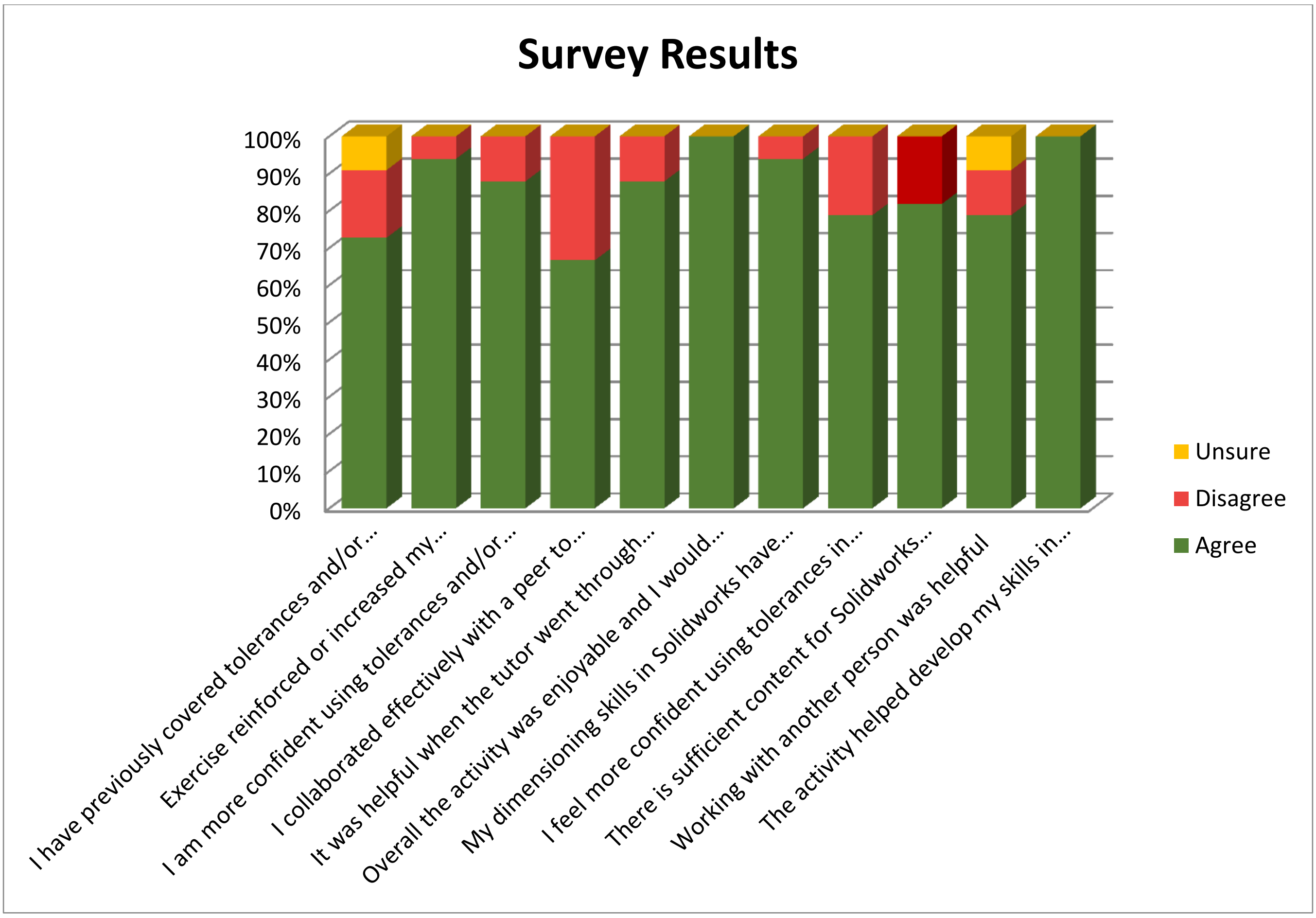


Figure 5.18: Chart 12 this shows the responses to the feedback questionnaire for the mechanical assembly activity. The green columns portions correspond with positive responses (the students agree with a given statement) whilst the red and orange column portions correspond with negative responses (the students disagree or are unsure)

5.14.6. Discussion based on feedback responses

The two statements to which the students unanimously agreed corresponded to questions 6 and 11,

Q.6 Overall, the activity was enjoyable and I would welcome more activities like it which use physical artefacts as a focus for the session.

Q.11 Do you think that the activity has helped you develop your skills in Solidworks further?

The other two statements with a positive response of at least 90% corresponded to questions 2 and 7,

Q.2 The exercise helped reinforce previously gained knowledge and/or provided me with new knowledge on tolerances and surface finish.

Q.7 My dimensioning skills using Solidworks have improved during the current academic year due to the practical work covered as part of this module in CAD/CAM.

The response to these questions leads us to the following conclusion:

Activities like this that utilise a physical artefact are enjoyable and more of them are desired by learners. This further establishes the value of activity and case based learning. It also helps reinforce prior knowledge in order to attain higher level learning. Question 2 related to tolerances and surface finish. Tolerances were covered during the prior year (year 1 of course) and a brief overview was given again prior to the activity. Surface finish (or quantifying roughness) was covered in sufficient depth prior to the activity and was a new topic to learners. They appeared to be more comfortable with this particular topic.

The statement to which 1/3 of the group responded negatively was question 4,

Q.4 I collaborated effectively with a peer to dimension the components by checking each other's work and making corrections accordingly.

This indicates that collaboration between two learners does not always work effectively, especially if there is considerable discrepancy in knowledge. This is because the most knowledgeable person decisively takes the lead to complete the task in a given time whilst the weaker learner resorts to being an observer. This statement was reiterated through question 10, but in a different form, as follows:

Q.10 Working with another person helped me in completing the exercise effectively. Was it helpful working with a peer?

Over 20% of learners had responded negatively to this statement which further substantiates the rationale to the response.

Our rationale on the negative response rate to this statement is further reinforced by the comments provided by students on the questionnaire.

Two statements with a positive response of at less than 80% corresponded to questions 1 and 8, regarding use of tolerances.

Q.1 I have previously covered tolerances and/or surface finish definition whilst either on this course or at another institution

Q.8 I now feel more confident that I can apply tolerances using Solidworks to stipulate a type of fit (clearance or transitional)

Our rationale for this response is founded on two possible causes. The first is that the topic of tolerances (limits and fits) was covered as part of a studio session during the end of year 1 by which stage learners had received all assessed work, therefore attendance had dropped when the topic was covered. Secondly, a considerable proportion of learners enter the course directly in to year 2. As we have no control over their prior knowledge (just assumptions based on qualifications) we cannot be assured of the necessary rigour to which they have covered the topic.

Two other questions that had both scored 12.1% negative were questions 3 and 5.

Q.3 I now feel more confident that I can complete drawings for production whilst also defining dimensional tolerances and surface finish.

Q.5 It was helpful to me when the tutor had gone through the recommended method for dimensioning and applying tolerances as it provided me with feedback on my work.

Based on the written comments provided by some students it is evident that negative response by 12.1% of respondents was due to lack of time and had reported that they wanted more time allocated to the activity. Two sessions over the duration of two weeks were entirely dedicated to this activity. We are unable to report on the association between the negative respondents and their attendance to both sessions or prior sessions covering the subject matter.

5.14.7. Conclusion in addressing the research questions

This case example demonstrates that it is viable to introduce micro learning activities which can be facilitated within the time constraints of timetabled classes.

Such active learning can incorporate several pedagogical frameworks in that it presents learners with several learning challenges such as Collaborative and Problem Based Learning within a single activity with opportunity for formative feedback from the facilitator as well as from peers.

Such activities also offer opportunity for learners to apply knowledge and skills gained from across a range of previous sessions from the course (be it from different modules and different levels of the course). This results in refreshing existing knowledge and reinforcement of learning. This also presents a more enjoyable method of learning whilst inspiring confidence in learners.

The activity also highlighted some the negative aspects of collaborative learning.

5.15. Summary

In this chapter we have presented the second case study and considered the application of Games Based Learning (GBL) as part of active learning in 3D Computer Aided Design (CAD) Assembly in mechanical engineering education. This case study evaluates results, qualitatively and quantitative. The chapter is self-referenced as it is based on an earlier publication. The work documented with this chapter goes beyond the previous published work in that it introduces and evaluates a new activity based on previous participant feedback and reports on the results of this.

The case study based on the revised activity is an extension to the original case study described in the same chapter (GBL) but with the gamification aspect removed. Its novel aspects lie in revisiting and reinforcing previously gained knowledge from technical graphics, CAD representation (for both 2D drawing and 3D assembly) and considers design aspects such as tolerances (limits and fits) and surface finish. The case is one in which a physical artefact is used by collaborative learners, working in pairs. It demonstrates how Integrated Concurrent Engineering Education can be put into action by consolidating, reinforcing and building upon previously gained knowledge.

Chapter 6 – Activity Based Learning (ABL) Using Gamification (GBL) in Mechanical Engineering Design Education: A Studio Based Case Study

Case example 3:

This chapter is primarily based on a pending publication.

6.1. Introduction

In case example 3 we aim to combine active learning by combining Activity Based Learning (ABL) and Game-based learning (GBL) activity as part of a holistic approach in supporting knowledge acquisition within a Mechanical Design undergraduate module. The case study evaluates activity based learning (ABL) by use of GBL as a tool to develop collaborative student learning. The activity described in this paper targets students' ability to engage in hands-on practical collaborative learning, utilising existing skills in order to collectively share and reinforce knowledge. The activity relies on knowledge acquired from several subject topics thus consolidating applications through a design studio based activity in the form of a game which brings about its own benefits in teaching and learning.

Although widely used in a selection of subject areas, the application of GBL in Engineering and Technology and its effectiveness is less explored and reported as a learning tool in Mechanical Engineering education. The case presents an approach in underpinning engineering education as part of a studio based activity for Mechanical Engineering Design. It explores the options and potential for Collaborative learning whilst offering students the opportunity to compete with peer teams for ranked position on a leader board. We report on the level of student engagement and the extent to which learning outcomes were met through the introduction of such an activity.

6.2. Background

With a significant rise in published work on the subject of gamification for the enhancement of teaching and learning in engineering education (Hamari J et al., 2014, Seaborn K and Fels DI 2015), a number of question remain open. These concern the effectiveness of such methods with a distinct lack of empirical evidence (Markopoulos et al., 2015) on the value of such games. The potential for such ABL can span over several positive facets including

- Collaborative learning
- Games Based Learning with all the spin off benefits (Mavromihales et al., 2018)
- Improved engagement and participation

- A holistic approach in consolidating subject area curriculum/knowledge.

In order to evaluate the effectiveness of Activity Based Learning in Mechanical Design a Game has been designed and incorporated as part of an intermediate module delivery (year 2 of engineering undergraduate study) on a BEng Mechanical Engineering course. The aim of the game is to partly fulfil the learning outcomes of a module in Mechanical Design whilst also reinforcing prior knowledge in associated topics such materials and process selection and detailed design.

We report on the outcomes of conducting active learning and report the feedback from students. We also report on their level of engagement and participation. Furthermore, we explore possible improvements for furthering the outcomes in ABL particularly in Collaborative learning as part of group work.

There were three module learning outcomes that we aim to fulfil through the application of this ABL activity and these are as follows:

- The ability to communicate graphically whilst demonstrating more than a basic level of the design process. This level should be commensurate with expectations of the level at year 2 (intermediate) of a Bachelors' degree in Mechanical Engineering.
- To be able to identify key areas of product design and analyse them in order to choose appropriate methods for their solution in a considered manner (this calls for both cognitive and intellectual skill)
- To be able to select and apply a range of communication methods appropriate to the product design analysis.

6.3. Facilitating the activity within the curriculum

Mechanical Design is a core module for undergraduates in Engineering and Technology studies. Reinforcing engineering scientific principles and elements of design through the application of studio based design projects has long been recognised and acknowledged as an effective means of achieving higher order cognitive thinking in mechanical engineering education (Krathwohl D 2002).

Several core modules precede the Mechanical Design module that form a fundamental part of the curriculum for the Mechanical Engineering Bachelor's Degree at the University of Huddersfield. The content of these modules is interlinked through theory and application in which the theory is reinforced by application. The modules used as examples and described in this paper intend to demonstrate how Activity Based Learning (ABL) and Game Based Learning (GBL), in a group context, can improve the learner experience during intermediate modules which are studied partway through a programme of undergraduate study. All modules will be defined in terms of content and learning outcomes and the way in which the content of these modules interlink will be clarified. We refer to three modules for which we apply ABL, GBL and TBL as part of a holistic method for enhanced learning:

- Manufacturing Technology
- Engineering Communications and Materials
- Mechanical Design.

The profiles of undergraduates that join the Bachelor's Degree is of diverse educational and training backgrounds which can vary from school leavers with GCSE (General Certificate of Secondary Education) Advanced level subjects, international school leaving certificates/diplomas or baccalaureate to mature apprentice trained or experienced students. GCSE Advanced level subjects offer the common route of entry by UK school leavers, into University undergraduate courses. There are an increasing number of students entering Higher Education with vocational level 3 qualifications (such as the Higher National Certificate and Diploma).

Mechanical Design as a formal module in Mechanical Engineering undergraduate programmes is usually introduced at intermediate level (during the second year of the three year course) once students have acquired prior knowledge in subjects such as graphical communication and use of Computer aided Design (CAD), materials, manufacturing processes and engineering science and analysis. The dilemma that many engineering educationalists are faced with is that too often students regard these subjects in isolation. Once they have met the learning outcomes of each and having passed the subjects at different stages of study, the context is lost. Any thought of application becomes vague. Design aims at bringing together the application science based subjects through an initial process of synthesis. It therefore bridges the gap between theory and practice. This requires a systematic approach or disciplined method of thought through which the creator creates, analyses, and eliminates solutions prior to embarking in the detail. This process is referred to as the design methodology. As an initial part of the module students are encouraged to practice by following though the design methodology process. It is a pursuit that challenges their creativity using analytical abilities. It is a complex process where extensive relationships need to be sub-divided into a series of simple tasks. The complexity of the process requires a sequence in which ideas are introduced and iterated.

Students usually embrace this process even though some struggle to systematically and methodically follow it.

In the later part of the module students are expected to consolidate prior knowledge and apply it in the detailing stage. For this they need to consider detail such as concise and unambiguous graphical representation, design for manufacture and assembly, materials selection and design validation though analysis.

It is through such a consolidation process that it becomes evident how past knowledge is either forgotten, overlooked or sporadic.

The aim of the activity described in this case study is therefore to prompt learners how prior knowledge is applied through examples in which they are assisted by collaboration with peers and guidance of the tutor whose role is as facilitator.

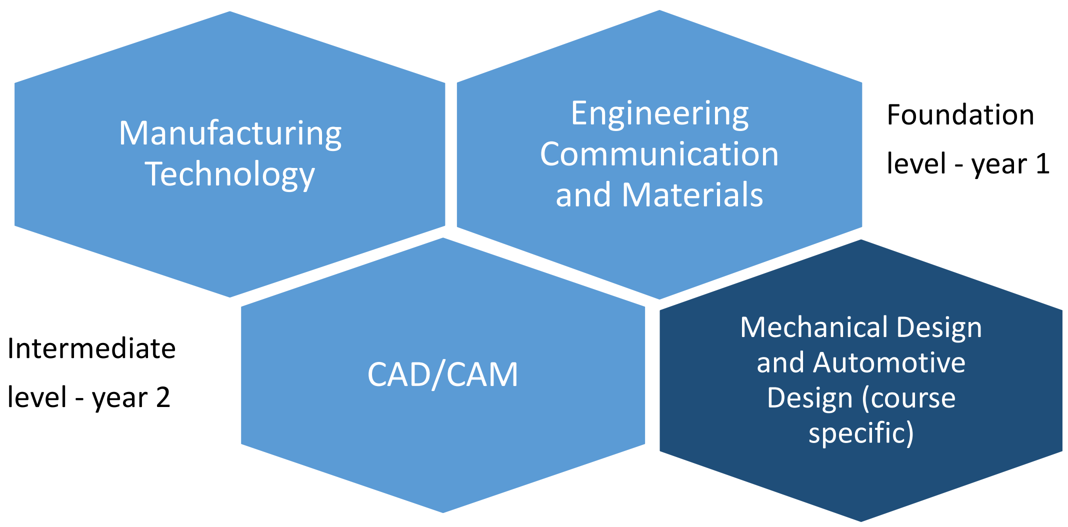


Figure 6.1: Positioning and timing of various modules for embellishing student knowledge for design application

6.4. Key research questions and outcomes

Several questions were posed prior, during and after the Activity Based Learning Activity. Guidelines for good practice in both ABL and GBL were followed (Mavromihales M., Holmes V., Racasan R, 2018).

Our research questions are as follows:

- Were students applying knowledge gained from formal didactic delivery sessions leading to the activity and was knowledge reinforced partly through collaboration with their peers?
- What were the motivating factors driving the students to perform better than their peers in the activity?
- Which students had performed better and why?
- How do students overcome gaps in knowledge through application of other skillsets and collaborative learning?
- Had collaboration enhanced or hindered certain participants and why?
- Did the activity serve as an effective means of formative self-assessment, to gauge standards of students against their peers?
- Was the activity enjoyable and was attainment improved as a result?
- Would the activity lead to improved performance in assessment?

6.4.1. Research methodology

The core methodology applied in this case study is Action Research (AR) as it is practice based and AR is of choice in critical educational methodology. It is applied in situations of educational social context in order to foster change within a natural setting rather than a removed context and entails active involvement by the research practitioner. A clear definition of AR is found in (Kemmis and McTaggart, 1988), as,

> "Action research is a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out." (Kemmis and McTaggart, 1988)

In order to address all the research questions we also consider the application of case study and grounded theory methodologies. AR remains are core methodology and other methodologies such as grounded theory and case study remain at the periphery. There are several ways in which case study methodology can be applied to gather data including, informal observation, surveys from learners and assessment results. All of these are applied in order to address the research questions as part of this action learning case study. Grounded theory methodology is used for supporting qualitative data as part of this research case study. It provides an outline for analysing the qualitative data by categorising similar responses together. The process can be repeated in order to compare data to previous occurrences in order to reach an end point or 'theoretical saturation' (Taber, 2000). At this point, additional data collection and analysis does not change finding significantly. The researcher did not proceed with several cycles of analysis of qualitative data for this case study, therefore, in isolation, it has not been applied fully. If, however, we analyse the qualitative data from all the case studies then the methodology becomes more evident in addressing the research questions.

Combined, through the applied methodologies, we gathered data by observation, learner feedback questionnaires and then quantified assessment scores for an element of an individual design task.

The experimental groups were formed freely based on gravitation due to social and/or cultural compatibility.

6.5. The challenge and motivation of this work

The challenge and motivation of this work lies in educating undergraduates and enabling them to think outside their traditional engineering subjects by applying knowledge in a more practical manner. The approach is a holistic one in that it links prior knowledge by bringing it together to be encompassed and applied in examples as part of a GBL challenge. The activity was intended to trigger learners' inquisition as to how and why a wide range of engineering artefacts are designed and made in a certain way. Inquisition is a great tool for acquiring wider knowledge and the activity was partly intended to inspire learners to do this by firstly undertaking this collaboratively as part of GBL.

A further challenge lay in providing a thoroughly 'robust' education to engineering undergraduates in order to equip them with the knowledge and skills to apply in a 'real world' environment. In order to achieve this, motivation and engagement are key. By facilitating them with the appropriate blend of teaching and learning techniques such motivation and engagement could be achieved and evaluated thorough both metrics and qualitative results.

6.6. Consolidation of prior learning leading to the activity

The activity was designed to integrate prior knowledge from several modules through collaboration amongst learners. The learning outcomes for each of the previously studied modules were as follows:

- Manufacturing Technology - knowledge and understanding

  For learners to possess a wide knowledge of manufacturing processes used for the manufacture and fabrication of engineered products and have an understanding of the appropriateness of such processes.

- Engineering Communications and Materials - knowledge, understanding and abilities

  1. For learners to have a working knowledge of 2D drafting using an appropriate standard such as BS, ISO, DIN etc. through both manual

and CAD methods. The use of an industry standard CAD package is required and a basic working knowledge of 3D CAD.

2. To understand and use common engineering vocabulary and terminology.

3. To be aware of the differences in the basic mechanical properties of materials and basic strengthening mechanisms for metals.

4. To be able to make informed decisions on the selection of materials.

5. To have the ability to design a basic engineering artefact or assembly including the selection and use of common engineering components and materials and to create engineering drawings which could lead to its successful manufacture.

- Mechanical Design – knowledge, understanding and abilities

1. To understand the design decisions taken by others by studying and analysing existing products.

2. To acquire the knowledge to investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.

3. To creatively establish innovative design solutions and represent them in the form of 3D and technical drawings whilst demonstrating the ability to select standard key mechanical parts (such as bearings, seals, transmission components, lubrication etc.).

4. To be able to ensure fitness for purpose for all aspects of the design problem. Having performed analysis to establish correct functioning, other aspects should include: production, operation and an awareness of the product’s eventual environmentally sensitive disposal.

5. Develop the ability to work in a team, understand design management issues and evaluate outcomes.

6.7. Structure of delivery of Mechanical Design and rationale

Mechanical Design as a formally delivered module on the BEng Mechanical Engineering course is an intermediate subject delivered at year 2. This is because students require certain prerequisite knowledge and skills prior to embarking in a design process and ultimately communicating a carefully considered solution with validation. Included in prior learning are skills such as effective graphical communication using both manual (technical and creative) illustrations as well as tools such as 3-dimensional Computer Aided Design (CAD). They must be able to refer to and apply relevant Technical Drawing skills in accordance to standards such as those that relate to technical representation of engineering components. They must be aware of how to validate a design through appropriate analysis using correct procedure for instance, the selection of a simple rolling element bearing or the analysis of a structural member using the Finite Element Analysis (FEA) method. Awareness of available materials and the production methods used to process these is also an important aspect of design for manufacture. With such skills and knowledge gained through prior learning learners are able to apply and extend their depth of cognition (Krathwohl D 2002) through design synthesis. The Mechanical Design module at intermediate level offers learners the opportunity to further hone their learning and understanding of the detailed design process once they have been guided through the creative design phase. This is achieved by means of a combination of lectures and by examining existing products in order to attempt the early stages of the design process in assignment work. The complete process will lead them from the conceptual stage to the final engineering design which will be represented by technical engineering drawings. The process may commence from identifying a need for a product though concept to detail design for manufacture.

Students are assessed on the following criteria:

- Further exploration of design options making systematic step by step decisions based on the application of morphological Charts
- Developing a concept to the extent of being able to convert it to a real product through detailed 'blue prints' resulting through stress analysis, materials selection, detailed part definition and selection of standard components such as fasteners.
- Detailed product definition through technical graphics

- Consideration to and appropriateness of manufacturing processes
- Consideration of materials and selection of suitable materials based on a process of elimination
- Design evaluation through the application of tools such as calculations, including stress simulation.

Learning Outcomes of the Mechanical Design Module

Evidence is sought through five key learning outcomes:

(a) To understand the design decisions taken by others by studying existing products and ability to apply the methodology to their own design challenges.

(b) Possess the knowledge to investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues.

(c) Be able to creatively establish innovative solutions and represent those solutions in the form of 3D and technical drawings whilst demonstrating the ability to select a number of bought-out parts.

(d) Ensure fitness for purpose for all aspects of the design problem. Having performed analysis to establish correct functioning, other aspects should include: production, operation and an awareness of the product's eventual environmentally sensitive disposal.

(e) Develop the ability to work in a team, understand design management issues and evaluate outcomes.

To help us in the process of effective delivery for improved learning we are implementing a blended learning approach in which we are incorporating prior learning in a pragmatic manner in order to improve higher order cognition. Figure 6.2 illustrates how we aim to achieve this with focus on design education through a combination of blended learning and gamification. The blend consists of prior didactic delivery, tutorials, computer laboratory work and studio activities prior to gamification.

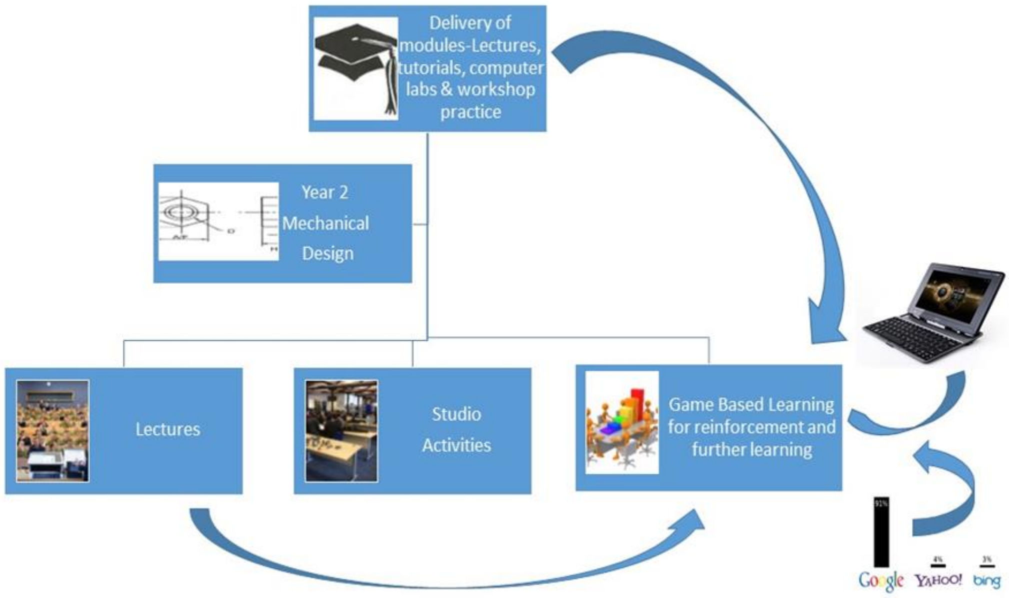


Figure 6.2: A blended approach to Mechanical Design education

6.8. Related work

Two clusters of collaborative learning are identified (Ross and Cousins, 1994) which are of practical value to teaching and learning facilitators. Credible alternatives, such as well-designed whole class instruction, are evaluated in one of Ross's clusters. Other studies have demonstrated that collaborative instructional methods lead to cognitive and affective gains for students at different levels, including undergraduate and post-graduate level (Johnson et al., 2000, Mavromihales and Holmes 2017). Such studies have confirmed that different collaborative structures have different effects.

It has also been recognised that there are amplifying and supressing factors in collaborative learning which would render them ineffective for certain learners. Low ability learners with poor social or interaction skills form a good example. In this case the experimental group consisted of mature and motivated undergraduate learners. It can therefore be safely assumed that the poor social or interaction skills did not hinder their learning. All learners possessed good communication skills which was evident from their interaction within particular smaller social groups to which they gravitated.

The other cluster of research on collaborative learning is useful to educators as it focusses on mediators or mechanisms that explain why collaborative learning is effective. It is necessary to consider practical observations and findings focus on what learners say to each other and how they say it during joint tasks. This will include implicit and explicit requests for help and contributions to their work, spontaneity in order to resolve a solution jointly (or to arrive at joint understanding) (Veenman et al., 2005, Webb et al., 2003). Such questions could also be addressed to the facilitator. Explicit answers would not be provided but further explorative questions would be offered as a form of guided assistance in order to arrive at a conclusion. Explanation and solutions are more frequently arrived at when students are working in structured collaborative groups than when not (Gillies, 2004). Instrumental or mastery-oriented help seeking is characterized by students alternating between giving help and receiving it.

Many of the student conversations during the activity were very naturally occurring in structure and therefore more like tutoring sessions than basic information exchanges. (Webb, 1989) reported six studies in which the ability to give explanations to peers correlated strongly with general ability. This resulted in dominance within a group by upper ability students. This is especially the case in collaborative learning classrooms (King, 1993). This dominance is even stronger when the group is required to produce a single product or arrive at a single solution. The danger here is that as an activity is task driven, pressure from more able students can create a case of ‘helpers system’ in which there is reduced participation by the less able in order not to slow down the group in the target driven activity. This can lead to a situation in which lesser contributors who believe that their offerings are of little value may respond by withdrawing from the task (Karau & Williams, 1993). This will inevitably nearly always offer a challenge to the facilitator of such collaborative learning activities. This was minimised in the study through grouping individuals within learning and social groups that they were already accustomed to working within. Furthermore, the required attributes for successfully completing the activity relied on more than just knowledge alone as they included skills in information finding as well as a small element of luck (as games usually require).

There are potential dangers with collaborative learning. Where help is needed and requested from peers, requests have to be explicit, focussed, repeated and directed to an individual who is willing and able to provide the help (Wilkinson, 1983). Excessive help seeking reduces peer esteem as such students are viewed to be ‘passengers’ or free-riders rather than contributors to group efforts (Weaver & Cousins, 2004). The skills set required to successfully complete this activity were multifaceted as it included the ability to search for information. This is skill that most young learners are capable of doing through extensive use of search engines and the web as a whole.

It has been argued that creating classroom structures that promote interdependence and provide explicit training is a prerequisite to student willingness to help each other. This approach has been central in studies by Johnson & Johnson, (1987) for Learning Together. Developing a positive climate strategy for group learning are also documented in Abrami et al., (1994), and Kegan and Kegan, (1994).

There is wealth of information available to assist teachers in the instructional challenges of group work. The work considered includes practical strategies with persuasive evidence about their effectiveness through:

- Frequency of high quality help giving
- Balancing student participation in group deliberations
- Encouraging learners to ask for explanations (a functional help seeking strategy)
- Improve the quality of student explanations.

These points alone amplify the positive effects of collaborative learning. They direct teaching of helpfulness, improving the social climate of the classroom, strengthening teacher interventions, and implementing reciprocal roles. One the most accessible method of achieving this is by providing students with generic prompts. This approach was demonstrated as part of the investigation in documented ABL activity, and supported by King, (1993).

Such prompts force students to think about the material to be learnt in different ways. Whilst exploring the material further through a structure of deeper processing, they are facilitating more effective learning than non-elaborative questions like ‘who’, ‘what’, ‘where’ and so on (King & Rosenshine, 1993). This prompt- based structure can be extended to student generated questions without guidance of elaborative prompts (King, 1997). In addition to enhancing student discourse in small groups, these prompts can be used to structure teacher interventions in small group deliberations and to move whole class discussions to deeper understanding.

6.9. Game development and applied pedagogy for enhancing game-based learning

At the root of development, Gagné's defined nine elements of instruction (Gagné, Briggs & Wagner, 1992) serve as a useful guide. The nine events are as listed in table 6.1 below. These are also as discussed and applied by Becker K, (2005), Becker K, (2010) and more recently by Mavromihales, Holmes and Racasan, (2018).

Table 6.1: A list of Gagné's Nine Events interpreted through Game Design and the association with the case study

1. Gaining Attention (Reception)	Students were informed and briefed of the activity during class. The element of competition amongst peers was disseminated. Anticipation was created at this stage.
2. Informing Learners of the Objective (Expectancy)	The need for recalling prior knowledge, gaining new information and trying to place themselves on the leader board defined the expectancy.
3. Stimulation Recall of Prior Learning (Retrieval)	This included past knowledge gained during prior modules as well as new information from current modules. Information finding skills would also be required.
4. Presenting the Stimulus (Selective Perception)	This took the form of physical engineering artefacts scattered around the workshops, design studio and the building in general. Questions were based on these.
5. Providing Learning Guidance (Semantic Encoding)	Learners were guided as to a strategy of approach which also complied with the rules of engagement. This was directed towards effective teamwork for information finding, sharing common knowledge, referring to lecture based information and making informed deductions.
6. Eliciting Performance (Responding)	Participants were observed and encouraged through guidance. In some instances clues were provided to encourage engagement with a sense of urgency for a higher ranking position.
7. Providing Feedback (Reinforcement)	Formative feedback was provided during the game as well as through debriefing during class.
8. Assessing Performance (Retrieval)	Learners were constantly aware of how well they were doing based on the number of game cards that were completed. Debriefing was facilitated in class sessions and at the end of the first week participants were aware of their ranked position on the leader board if they succeeded to be amongst the top 50%. Tactics could then be reviewed.
9. Enhancing Retention and Transfer (Generalization)	Greater awareness of what is required in the form of detailed information for transfer to design reports for improved assessment scores.

The nine events can be embodied, directly or indirectly, to game elements. They are widely used as a benchmark for evaluating educational games (Becker K. 2006). The right column of table 6.1 discusses how the principle has been implemented in the gamification aspects of the case study.

Reference was also made to generic guidance of Gamification of Learning: good versus bad practice, which can be seen in table 6.2.

Some of the key questions that were addressed related to the following:

- Application of skills and knowledge gained prior to the game
- Fun in participation
- Collaboration with peers (beneficial, fun or hindrance?)
- Gauging of self-performance (formative feedback of ‘how am I doing’ compared to my peers).

Leading up to the end of year submission of individual projects, students are invited to take part in studio based group activities. Such activities may include writing a comprehensive Product Design Specification (PDS) with customer requirements and applying the 6-3-5 creativity technique (https://www.youtube.com/watch?v=TR1i1PPd8ZU) [Accessed 20-12-2018]

Studio assigned time gave opportunity for the introduction of a new GBL activity. Gagné’s Nine Events of Game Design (Table 6.1) were used as a guide to formulate the game.

King, (1997) and Gillies et al., (2010) present a strategy that structures the interaction within a collaborative group to stimulate the cognitive and metacognitive processing appropriate to complex learning tasks. In metacognition processing, learners are given the opportunity to monitor, regulate and evaluate their own thinking and learning (Hacker, 1998). The process is realised through interaction with peers during which they use existing knowledge, like building blocks, in order to deduce an answer to a question or solution to a problem. If knowledge is lacking in individual members, a process of self-awareness becomes apparent. Whilst knowledge from peers is gained, weaknesses in individual participants become apparent. This strategy helps in monitoring comprehension. Therefore, although some of the questions encouraged collaborative learning in which learners combined their knowledge to answer a clear-cut question or reviewing and retelling material already covered in class, other questions encouraged cognitive advanced goals, which called for learners to achieve a deeper comprehension of material and construct new knowledge. The latter requires interaction with higher order thinking which results in complex learning. This is known as 'Guided Reciprocal Peer Questioning' (King, 1989, 1990, 1994, 2006; King et al., 1998) and is intended for structuring interaction that promotes higher-order thinking and complex learning. Its effectiveness has been demonstrated in a number of controlled research studies conducted in classroom settings. According to socio-cognitive learning theory (Vygotsky, 1978), cognitive change is strongly influenced by interaction and activity with others. Different interactions promote different kinds of learning (Webb & Palincsar, 1996). Fact-based interaction is ineffective for complex tasks, which involve analysing and integrating ideas, constructing new knowledge and solving novel problems as they seldom elicit responses that are sufficiently thoughtful (Cohen, 1994).

Table 6.2: Good versus Bad Gamification in the Classroom https://www.researchgate.net/project/A-new-book-Gamification-A-Practical-Guide-for-the-Classroom [Accessed 2/11/2018]. Reproduced with permission of the author (K.Becker)

Gamification of Learning: Good VS Bad		
© K.Becker	Good	Bad
Point Values for Quests	Reflect level of difficulty & engagement. *EG. 10 XP for small quiz; 250 XP for term project.*	Assigned arbitrarily. *EG. Everything has point values in the 1,000's*
Scoring System	Strictly Cumulative. EG. All scores are simply summed for the final grade.	A simple mapping from traditional compartmentalized system. EG. Each scored task fills a specific scoring "slot".
Quests	Wide variety, large and small.	Simple translation of traditional system. EG. 6 assignments, 1 midterm, 1 final exam.
Quests	Varied tasks. More tasks to choose from than needed for full score.	The SAME assignments, quizzes, and exams, just now called "quests".
Competition	Students compete against themselves (previous scores) or have access to anonymized class rankings.	Students compete against each other.
Leaderboards	Anonymized. Students can see where they rank, but others cannot see who ranks where. NO-ONE is singled out.	Student identities known. Winners and losers obvious.
Narrative	Theme and approach complements subject matter, student level and interests.	Imposed from above. Connection to subject matter thin, contrived, or completely non-existent.
Badges	Awarded for genuine achievements. Publicizing badges optional (i.e. students choice)	Awarded for trivial acts. EG filling out a form, wearing a hat on Hat Day, etc.
Practice & Mastery	Re-do's encouraged. Resubmission allowed. Some tasks repeated in different ways.	Every task is a one-off. No resubmissions.
Path to End	Customized. Allows for multiple routes to success. Clear. Defined at beginning of term.	Lock-step. One path for all. Every task is revealed JUST before it is given out,

Webb et al., (1996) have shown through their research that when learners are given instructions to work collaboratively, they generally fail to interact at a planful level unless they are guided and prompted explicitly by the teacher. Learners also fail to activate and use their relevant prior knowledge without specific prompting.

This is further supported by Graesser et al., (1994) on constructionist theory of comprehension. It builds coherent highly-integrated mental representations (Kintsch 1988).

Examples of how some basic comprehension questions may be formatted are:

'What does….mean?

What causes…..to occur?

Describe ……in your own words

Whilst questions that pose more thought-provoking may be formatted like this:

What is the significance of ….?

How are ….and …. similar?

What is a new example of ………?

What is the difference between …. and …..?

The quiz questions formed a mixture to include both 'memory' or 'review' questions as well as 'thinking questions' which provoked thought. Guided Reciprocal Peer Questioning that uses thought-provoking questions to induce cognitive processes in learners has been shown to be effective particularly with more mature learners where a better understanding of content was demonstrated by learners at University level, particularly in small study groups.

6.9.1. "Design studio quiz game" design

The comparison of good vs bad practice summarized in table 6.2, was used as a guidance to evaluate practice of gamification activity, in "Design studio quiz game" presented in this case study:

- Questions varied in difficulty and marks were awarded accordingly as 2, 4 or 6 (**point values** for **quests** and **scoring system**).
- Some questions were awarded a negative score if answered incorrectly. The points system (including particular questions that were negatively scored for incorrect answers) were not disclosed to students.

- There was a large choice of questions due to the number of game cards incorporated as part of the game.
- The choice of questions was significant due to the number of game cards that formed the game.
- **Competition** existed between teams who strived for a place on the **leader- board** which displayed the top 50% of groups.
- All subject matter was linked to existing and previously studied modules (**narrative**).

During a scheduled class, once the activity had ended, the final top three winning teams were announced. Some of the key questions contained on the quiz cards were addressed at a stage post-completion of the gamification activity (**practice and mastery**).

6.10. Sample questions and significance to higher order thinking

Figures 6.3(a) and 6.3(b) show examples of component which featured on two of the quiz cards. The associated questions were as follows:

Figure 6.3(a) images were associated with the tasks/questions:

1. Identify the surface finish indicated by ‘A’ and show it would be represented on a technical drawing.
2. What is the most likely method of manufacture of the complete component?
3. By what machining method is the surface finish at ‘A’ achieved?

Figure 6.3(b) images were associated with the tasks/questions:

1. Identify the surface finish indicated by ‘A’ and show how it would be represented on a technical drawing.
2. How may this surface finish achieved?
3. Define the nominal roughness number range achievable by your answer to Q.2

4. What can we deduce from the features shown by arrow ‘B’ and the area within the black oval line?

5. What is the significance of the holes as shown at arrow ‘C’?

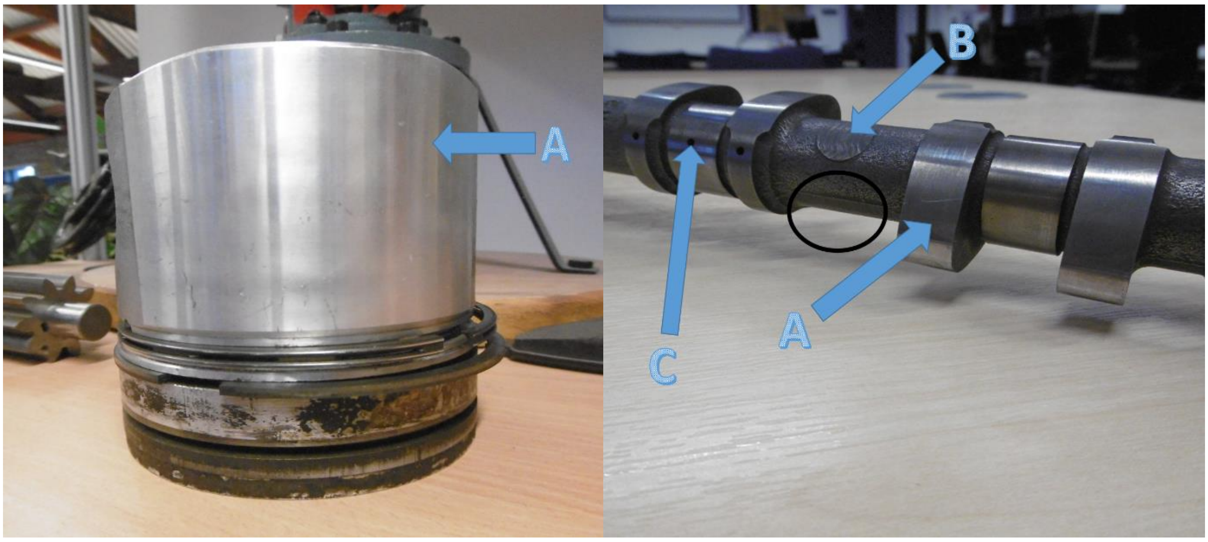


Figure 6.3: (a), left and (b), right, figure illustrate the components featured on the quiz game cards. Associated questions relating to these components have been given above

One of the challenges in planning the ABL activity was careful consideration of the wording of questions. This was important because, as the activity required cooperation between peers, the intent was to partly challenge small groups of participants in higher order cognitive thinking whilst promoting group interaction to achieve those goals. To do this, certain questions, but not all, had to go beyond mere information retrieval of previously-acquired knowledge but to engage in thinking analytically about that knowledge. Learners were therefore encouraged to use what they already knew, often collectively, in order to construct new knowledge. This will encourage the learners to solve new problems and address new issues.

It was for this reason that, in this case study, learners were encouraged or guided to engage in a particular pattern of dialogue. For example, if a question required that a small group of collaborating learners explore possible methods of manufacture for an identified artefact, the choice may have been choosing from a wide range of possible methods. To avoid the blind recollection of as many manufacturing methods they could identify between them (using basic memory and knowledge), they were encouraged to consider materials limited to process but also the surface finish achievable by each process and associate the information collectively to the artefact in question. This guidance therefore encouraged higher order cognitive thinking and making connections between new explored material (by searching during the activity) and relevant prior knowledge. This interaction induces learners' sophisticated cognitive processes such as inferencing, speculating, comparing and contrasting, justifying, explaining, questioning, hypothesizing, evaluating, integrating ideas, logical reasoning and evidence based argumentation.

6.11. Game specifics – Mechanical Design studio activity game

A large number of existing engineering components (that are freely accessible in physical form in order to allow for exploration) were identified. These components all existed and located within certain accessible areas of the Department (including the workshops, the design studio, display areas and research laboratories). The components were photographed and catalogued on to game quiz cards. Each component image had a number of questions associated to it. Examples of four such quiz cards are illustrated in figure 6.4.

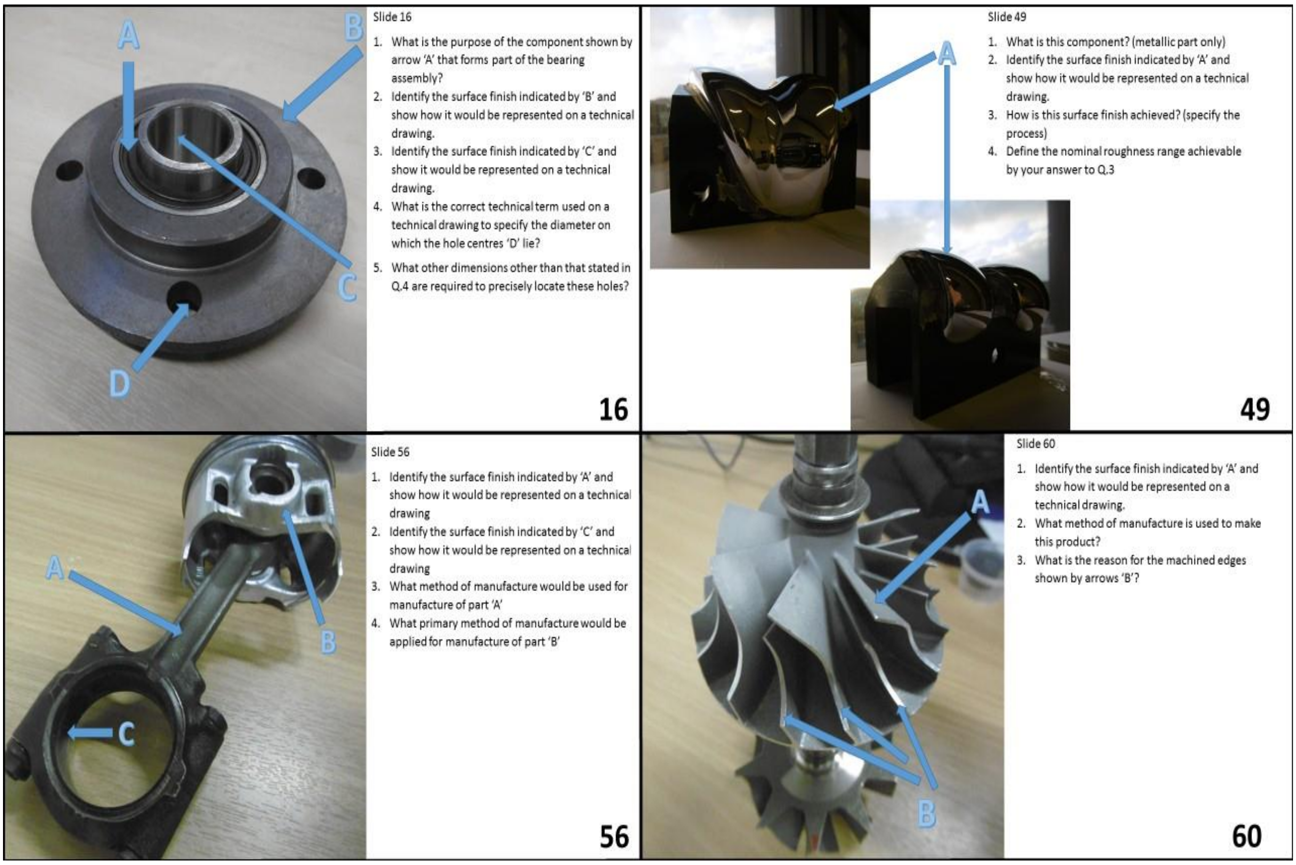


Figure 6.4: Illustration showing samples of four quiz game cards containing component image and associated questions

6.12. Game definition and rules of conduct

During a scheduled studio session individual participants would form groups of no more three and no less than two members. The activity was time limited and entailed collective and collaborative knowledge and skill. Like most games, there was also an element of luck depending on the cards drawn, the number of questions per card and level of difficulty of questions. The required knowledge was expected to have been obtained from delivery of lectures in the Mechanical or Automotive Design and other modules (both at foundation and intermediate levels) and gave the opportunity to apply and reinforce knowledge through collaborative learning. The skill element would be evident in the manner in which the participants would explore or deduce the required information by using sources of information available to them (including the internet and reference lecture notes within the Virtual Learning Environment) and through collaborative reasoning.

Participants would be allocated three cards at a time, which are selected randomly (each part contains a different component), and once these were completed they would then request more cards. Each question would have points associated with it, the precise weighting of which was not known to the participants. One in three questions would carry a negative score, or penalty, which was not disclosed to the participants. This would only be applied to easier questions that the students were expected to know. Questions carried either 2, 4 or 6 points depending on level of difficulty, but not disclosed to participants. All questions had to be attempted before the quiz cards could be returned to the facilitator and participants had to identify and physically handle the part on the quiz card (guidance and direction as to the whereabouts of the part was provided for this).

Specifically, the questions covered certain aspects of mechanical design including:

- Surface finish
- Applied manufacturing technology associated with processes
- Materials
- Technical graphical communication
- Tolerances.

Some of the topics such as surface texture definition, tolerances and element of mechanical design (i.e. definition and selection of bearings) were covered as part of lecture based delivery for the same module. The game offered further opportunity for reinforcing knowledge though application by collaboration.

As part of the rules, groups were required to work collectively and not to fragment to work independently, even if they considered this to be advantageous. They were also not allowed to exchange quiz cards. To break the rules (including segregation and exchange of cards) they would risk group disqualification.

The activity would be run over consecutive weeks and at the end of each session the tutor would sum up the points scored by each team across several group sets. The trial was run over a duration of two weeks but there was no reasons why, once proven to be successful, it could not be run for more than two weeks. A leader board within the VLE would display the ranking order for each team but only for the top 50% of teams. The leader board would be revised following each session that the activity was run thus introducing an element of competition and an attempt or bid for a top 50% positioning. An example of the leader board is shown in table 6.3 where the names of individual students are omitted are replaced by group letters, for the purpose of this paper.

It was evident from student attendance, engagement and participation that the activity was well received by all the students. Attendance was generally excellent for the activity sessions. Students were further enticed by being awarded points towards their overall grade for the module, for attending and actively participating. Even though this score was insignificant, it appeared to have resulted in good overall activity involvement.

Other than introducing a learning activity with an element of fun and competition, there were several other objectives:

- For students to be more aware of engineering artefacts that they come across on a day to day basis and question their related engineering attributes (raise awareness and inquisition)
- To apply and reinforce existing knowledge obtained through various engineering modules

➢ To encourage them to think in greater detail and concise definition with regard to their own individual mechanical design assignment

A short feedback questionnaire was issued at the end of term in order to gather qualitative feedback from participants on how they perceived the activity from various aspects including:

- Applying previous knowledge
- Whether they regarded the Activity Based Learning event as being fun, despite of, or especially due to, the element of competition
- Effective collaboration with peers
- Formative self-assessment
- Clarity relating to requirement and rules of engagement
- Relevance of activity to course content.

The appraisal of the answers to the above questions is encouraging and students have indicated that they are satisfied with the format of this learning activity. Detailed analysis of both the qualitative feedback and quantitative impact on their individual design work are reported in later in this chapter. Table 6.3 shows the final rankings of groups.

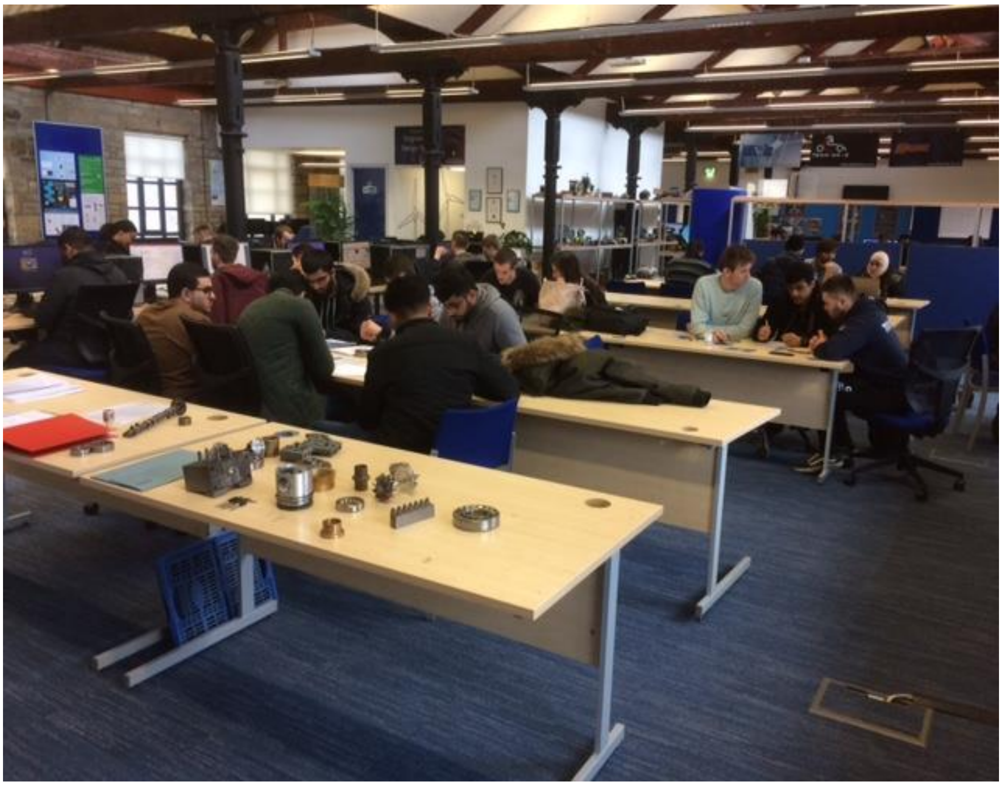


Figure 6.5: Studio ABL with Gamification in action

Note: ABS indicates that a member of the group was absent during that particular session

Table 6.3: Final group ranking table. The names are disguised for anonymity and only group names are displayed. Individuals were assigned to a group. Participants could follow their progress and compete for a place on the rankings table. Only the top 50% of the participating groups would be displayed in the league tables. Positions could change during consecutive weeks of game deployment. This introduced an element of competition in an effort to be part of the top 50% of participating groups

Date:19/3/2018								
Team	Day of Attendance	Tutor	Score	Week	Score	Week	Total	Overall Ranking
GROUP J	Tuesday	MM	29	1 of 2	23	2 of 2	52	**1**
GROUP M	Tuesday	MM	20	1 of 2	11	2 of 2	31	**5**
GROUP C	Thursday	MM	19	1 of 2	11	2 of 2	30	**6**
GROUP N	Tuesday	MM	18	1 of 2	11	2 of 2	29	**7**
GROUP K	Thursday	MM	16	1 of 2	15	2 of 2	31	**5**
GROUP G	Thursday	MM	16	1 of 2	12	2 of 2	28	**8**
GROUP A	Tuesday	MM	15	1 of 2	27	2 of 2	42	**2**
GROUP T	Tuesday	MM	13	1 of 2	26	2 of 2	39	**3**
GROUP S	Tuesday	MM	11	1 of 2	ABS	2 of 2	11	**11**
GROUP D	Thursday	MM	10	1 of 2	14	2 of 2	24	**9**
GROUP H	Thursday	MM	9	1 of 2	ABS	2 of 2	9	**11**
GROUP B	Tuesday	MM	7	1 of 2	16	2 of 2	23	**10**
GROUP P	Thursday	MM	7	1 of 2	31	2 of 2	38	**4**
GROUP F	Thursday	MM	7	1 of 2	1	2 of 2	8	**13**
GROUP M	Thursday	MM	3	1 of 2	ABS	2 of 2	3	**16**
GROUP R	Tuesday	MM	ABS	1 of 2	9	2 of 2	9	**12**
GROUP E	Thursday	MM	ABS	1 of 2	5	2 of 2	5	**15**
GROUP L	Thursday	MM	ABS	1 of 2	6	2 of 2	6	**14**

6.13. Evaluation

The design studio quiz game was included in the delivery of the Mechanical Design module and its 'sister module' of Automotive Design. Both modules combined account for approximately 125 students. The activity was conducted over a period of two weeks encompassing learning associated with engineering artefacts as illustrated in figures 6-3 and 6-4. The activity was repeated over two consecutive years (academic years 2017/2018 and 2018/2019) in order to compare and evaluate results between control and experimental groups over the duration.

Once the activity had been completed and the top scoring teams had emerged, learners were given formative feedback on performance and how this could have been improved. Discussion sessions helped resolve queries that arose regarding certain questions relating to artefacts used as part of the activity. During the evaluation certain questions were addressed through a feedback questionnaire in order to establish whether the activity had generated a positive learning experience or had the activity succeeded in achieving the following?

1. Encouraged learners to apply skills and knowledge previously gained on the course and were these further reinforced during the game?
2. Was the GBL activity fun to participate in and did it introduce an element of competition amongst peers within a GBL environment?
3. Encourage effective collaboration with peers in order to address key quiz questions?
4. Did the activity provide a means of formative assessment (a means of gauging self-knowledge against that of peers)?
5. Was the activity a refreshing and welcome activity during studio sessions?
6. Were participant requirements made clear prior to the game and were the rules of conduct also made clear?
7. Did team working help in completing the tasks effectively?
8. Should ABL be more widely applied?

9. Was the activity interesting and relevant to the module and course (as perceived by learners)?

The feedback questionnaire consisted of nine questions. A copy of the questionnaire, which was issued to over 100 participants, is included in appendix A and the analysis of students' answers to the given questions is detailed as part of this chapter and summarised later in chapter 8. This formed the basis for the qualitative analysis.

The basis of the questionnaire was to establish the views as to whether students had perceived to have gained from the overall learning experience. One of the longer term research questions is whilst students may respond positively to an ABL approach to teaching and learning, do they actually benefit to a greater extent, beyond the activity. Questions 8 was included to enable the quantification of students who desired for more sessions to be delivered in this manner whilst Question 9 tried to establish the students' perceived relevance of content, to their course. Questions 3 and 7 referred to aspects of Collaborative learning whilst questions 2, 5 referred to aspects of gamification design (Csikszentmihalyi, M. (1996), Gagné, Briggs & Wagner, (1992)).

6.14. Summary of findings, analysis and conclusions from feedback questionnaires

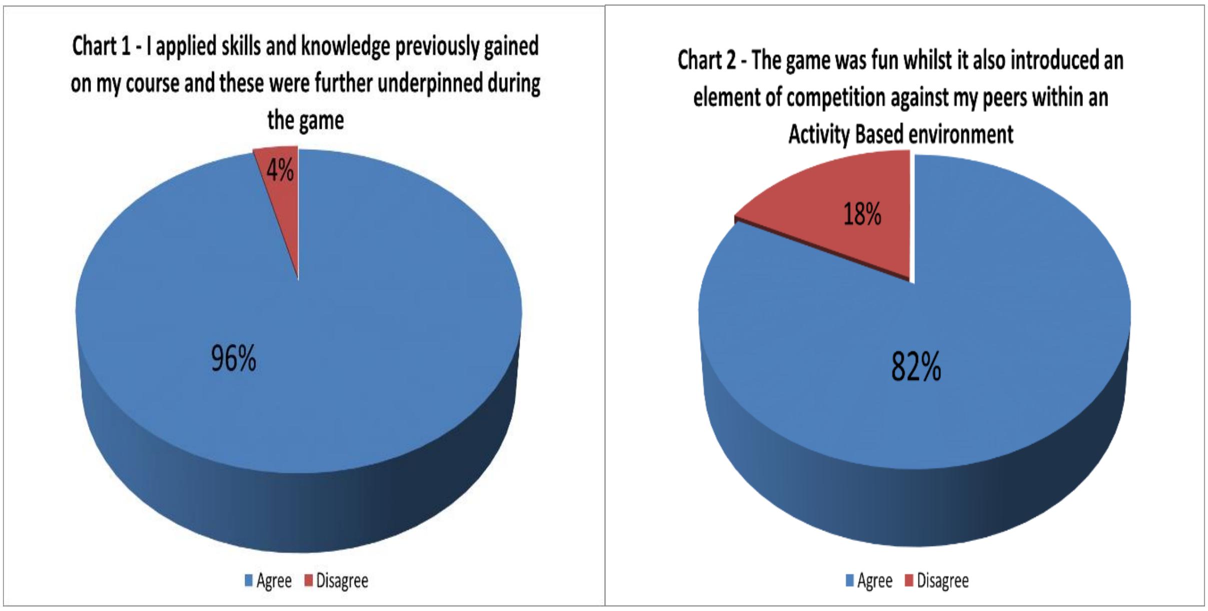


Figure 6.6: Charts 1 and 2 correspond to the responses of questions 1 & 2

Charts 1 and 2 (figure 6.6) correspond to the responses of questions 1 & 2. These indicate that 96% of learners felt that they had applied previously gained skills and knowledge which were further underpinned during the activity. A small number of students felt that this was not the case. Although unclear, these responses may have been from a minority of students who had entered the course directly into year 2 thus not have studied specific modules in manufacturing technology, materials and engineering communications delivered in the first year of the course. Differences in courses between various institutions can hinder continuity and link with prerequisites. The 82% response to the game being fun and competitive was again positive, however, effort was required by participating learners and the pressure to perform as a result of gaining a place on a leader board may have dampened the enthusiasm of the 18% of respondents who disagreed with this statement.

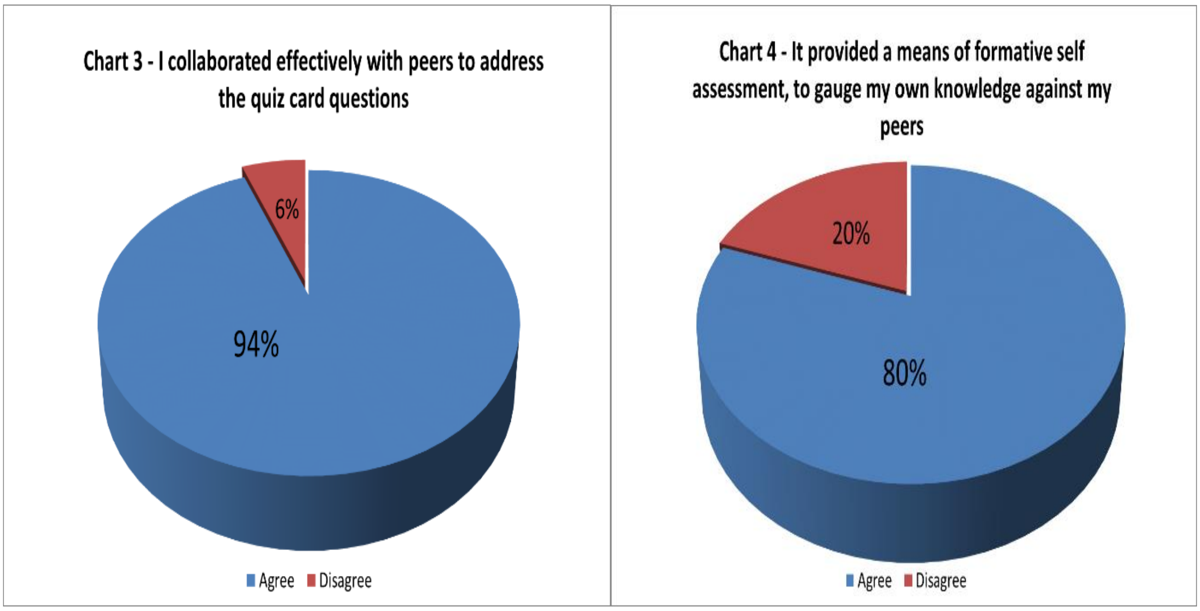
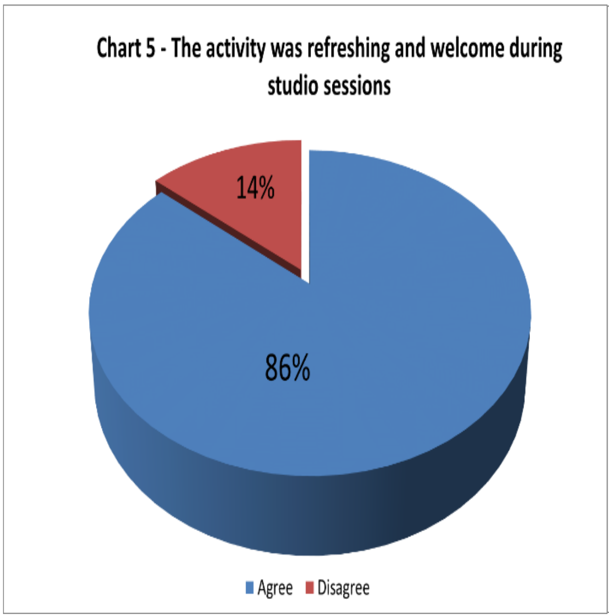


Figure 6.7: Charts 3 and 4 correspond to the responses of questions 3 & 4. 94% of learners indicated that they collaborated effectively with peers to address the quiz card questions

The high score of success indicated by this question regarding collaborative learning was higher than expected. Collaborative learning has been well established and proven to be successful in numerous educational empirical studies, time and time again (Johnson and Johnson, 2002). Johnson and Johnson (2002) base it on social interdependence theory that underlies the most widely used collaborative learning procedures. It has been validated by hundreds of research studies (Johnson & Johnson, 1974, 1987, 2005). Social interdependence exists when the accomplishment of each individual's goals is affected by the actions of others (Johnson and Johnson, 2005). They therefore promote each other's efforts to achieve the goals. Negative interdependence exists when individuals perceive that they can obtain their goals if and only if the other individuals with whom they are collaboratively linked fail to obtain their goals. Based on interdependence theory, the high percentage score (94%) is believed to be attributed to groups (of maximum three members) that were self-assigned in the knowledge that they were able to collaborate. The small number (6% of respondents) that disagreed with this statement were likely to have had a member absent during part of the activity. Chart 4 indicates that 80% of participants felt that they had gained a means of formative feedback as to the level of their knowledge as compared to their peers.



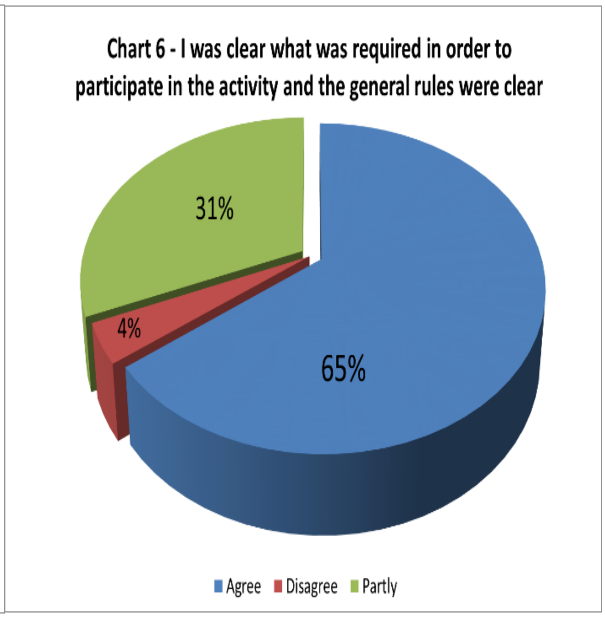


Figure 6.8: Charts 5 and 6. Chart 5 indicates that the activity was refreshing and welcome during the studio sessions. Chart 6 indicates the result of "I was clear what was required in order to participate in the activity and the general rules were clear"

Figure 6.8 Chart 5 result of the activity was refreshing and welcome during the studio sessions. and Chart 6 result of "I was clear what was required in order to participate in the activity and the general rules were clear".

Chart 5 indicates that the majority (86%) of students regarded the activity was a welcome change for studio sessions. The 14% that disagreed may have done so due to the required effort and competitive element necessary to partake in active learning session. The question was straight forward without ambiguity. Chart 6 indicates that nearly a third of participants were not entirely clear of the rules of conduct. This may have been due to absenteeism from a class based session during which the rules were covered, a situation which can improve in future by reiterating across more than one session and also making these accessible to students through the VLE, but also asking students to tell me what I have asked them to do. These were also displayed throughout the duration of the game. Questions regarding rules of conduct were addressed during the activity.

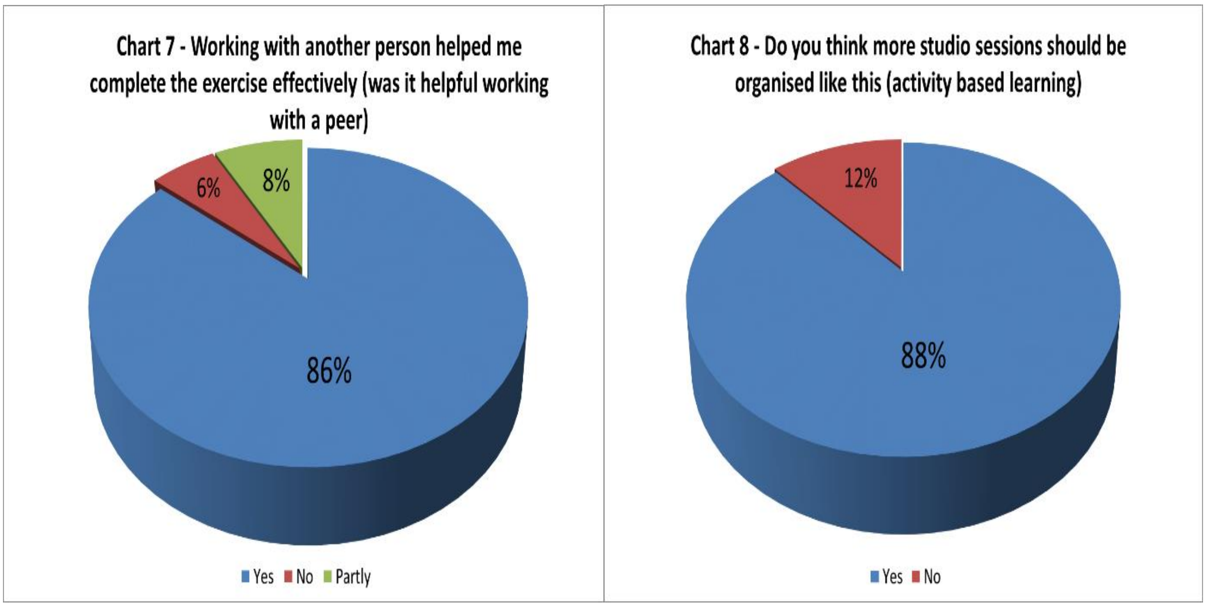


Figure 6.9: Charts 7 and 8. Chart 7 result of the Working with another person helped me complete the exercise effectively and Chart 8 shows the result to "Do you think more studio session should be organised like this"

The results indicated by Chart 7 directly correlate with the responses to question 3 (see Figure 6.7 Chart 3), in that 96% of respondents agree that cooperation with peers was of benefit in completing the activity. The responses to question 8 are indicated in Chart 8 which correlate closely with question 5 (see Figure 6.7 Chart 5), indicating that 88% of participants would like more Activity Based Learning.

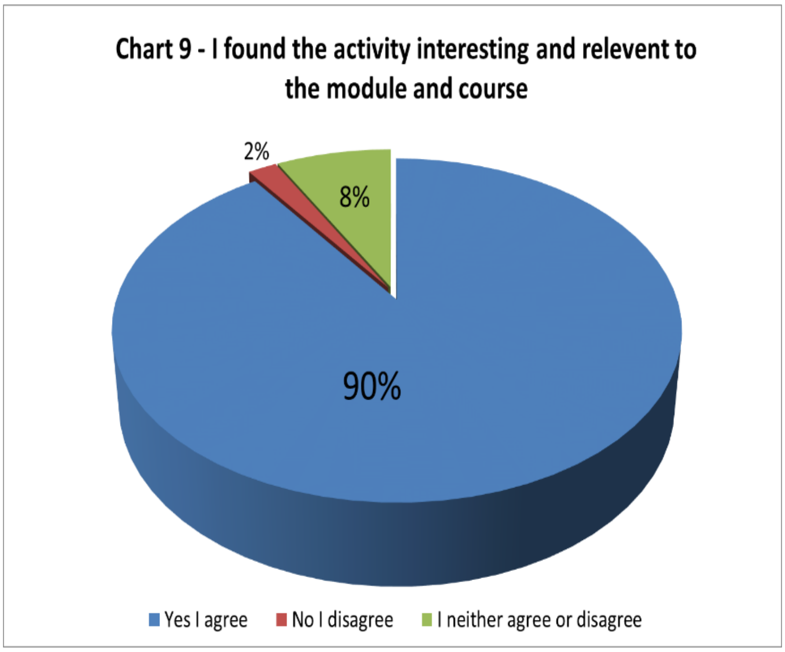


Figure 6.10: Chart 9 shows the result of "I found the activity interesting and relevant to the module and course"

Chart 9 indicates that 90% of learners regarded the technical content as interesting and relevant to their course. 2% disagreed and 8% were neutral. These results can be explained in that leaners often have misconceptions as to what is relevant to their chosen field of study as they are unable to see the wider picture.

The fact that 90% had responded entirely positive is testimony to the engagement by the majority of students who took part in the game.

6.15. Further evaluation for differences in assessment results – quantitative analysis

At the end of year, students submit an individual project report as part of the Mechanical Design module. A similar report is also submitted for assessment by students on the equivalent module in Automotive Design. This submission consists of a report and a set of technical drawings.

A marking scheme was devised so that half of the available marks for this assignment are allocated to elements of detailed design such as applying tolerances, correct dimensioning, surface finish considerations and manufacturing & materials considerations. This formed part of an assessment rubric.

It was noted that there is a difference in performance in this assignment for current student cohort and the previous year's cohort (comparing students from academic years 16/17 and 17/18). As the difference in overall scores was not sufficiently significant for a solid conclusion further analysis was necessary. In Mavromihales and Holmes (2018), changes in performance were gauged by comparing the profiles, in terms of tariff points at entry point to the course, between two groups of consecutive years of entry on to undergraduate study. In this case this was not viable due to changes in the currency of the tariff points. It was therefore not possible to make adjustments for discrepancy in the levels of qualifications between the control group and the experimental group. This would lead to comparisons between experimental and control groups in the subsequent year, for the same activity. The overall profile of learners would therefore be known to be similar. Table 6.4 indicates a broad overall breakdown of learner backgrounds, specifically for the year group cohort that took part in this activity. These are also represented in figure 6.11 Chart 10.

Table 6.4: Breakdown of learner qualifications at the point of entry to the Bachelors course

Qualification at pre-entry to Higher Education	Percentage of learners
Level 3 vocational STEM (Science Technology Engineering Maths) qualification at National Certificate level	20%
Other level 3 vocational qualifications (not STEM) at National Certificate level	22%
GCE Advanced Level subjects in Mathematics and Science or Technology subjects (primarily from UK Colleges and High Schools)	18%
Mature students having studied on a recognized Access to Higher Education Course	1%
Transfers from other HE institution	18%
Non UK first bachelor's degree	2%
Diploma-allowing direct entry to year 2 of Bachelor's degree	19%

There is insignificant difference in learner profiles over the two years. Direct entrants to year 2 have been accredited for prior learning. The results are also represented in Figure 6.11, Chart 10 along with a brief explanation of level 3 qualifications.

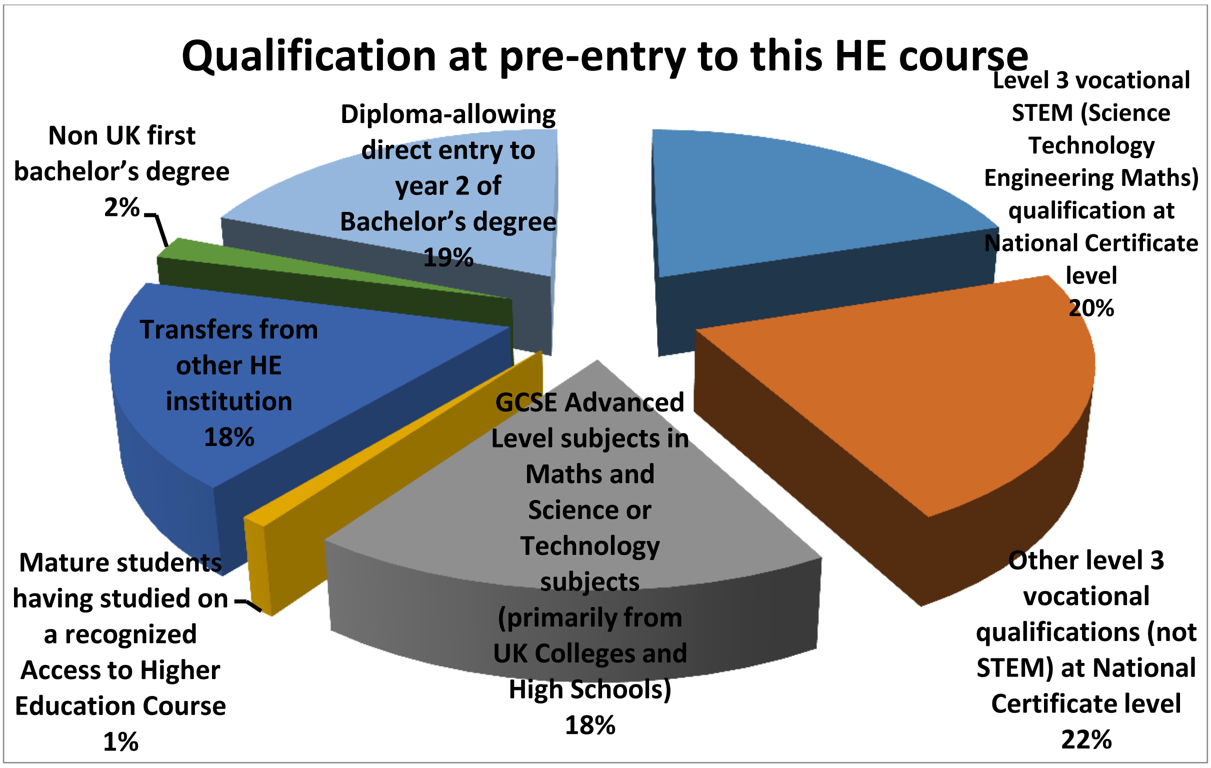


Figure 6.11: Chart 10 Range of qualifications of participants at point of entry to Bachelors course in Higher Education for cohort of students in this case study

NVQs are national vocational qualifications. They are based on learning in the workplace and are designed to accredit work-based skills. An NVQ level 3 is equivalent to two or more GCE (General Certificate of Education) Advance level but more general and vocational based.

6.15.1. Initial analysis of results

As a separate measure, we had also compared the performance of individuals who were in groups that had ranked amongst the top ten finishers in the activity. Results were also compared with another cohort of students who participated in the same activity but as part of a similar 'sister' module, in Automotive Design. Results in performance were unsurprisingly similar in that the top scoring half of groups accounted in a 10% improvement in students' individual scores for the end of year individual detailed design project. This alone could not be conclusive as it could be alleged that it was bias in that the more able students would inevitably perform better during the game as well as in their final individual assessment. Students who ranked amongst the top ten in the activity were more motivated and would have scored better individually in any case, or whether participation in the gamification activity had assisted them to achieve better results, individually. However, it is evident that students who had performed outside the top ten ranked groups had an absent member during one activity session, which clearly hindered the group performance. Other possible underlying issues of weaker performing groups in the activity will be explored and discussed later and addressed as part of future work in chapter 10.

6.15.2. Further analysis of results

All students on the module submit an individual design project at the end of the academic year. In assessing their work tutors work to a rubric in which one criterion is based on detail design (consideration of tolerances, surface finish, correct graphical representation etc.). A score out of 4.5 was allocated for this criterion. For further analysis, we considered the scores of students on the Automotive Design module during the academic year 2017/2018 and 2018/2019. This consisted of a smaller number (15 students) who had participated in the activity during the academic year 2017/2018 and a similar number of students who had not participated in the activity during the 2018/2019 academic year. The overall difference in individual assessment performance between the two cohorts was 10%.

As we had a significantly larger number of students on the Mechanical Design module we were able to work with correspondingly larger control and experimental groups and consider differences in scores for the element of assessment that was associated with the activity. To do this we compiled the data in a form that could be presented in a score frequency graph (thus comparing non-participating Automotive Design Students with a number of non-participating Mechanical Design students and all participating Mechanical Design students). Figure 6.12, Chart 11 illustrates the frequency analysis (or score density graph). This shows an overall improvement in assessment of students who had participated in the activity (experimental group) as compared with students who had not participated (control group). Assessors were unaware of the identity of activity participants when assessing of individual design reports, thus avoiding bias.

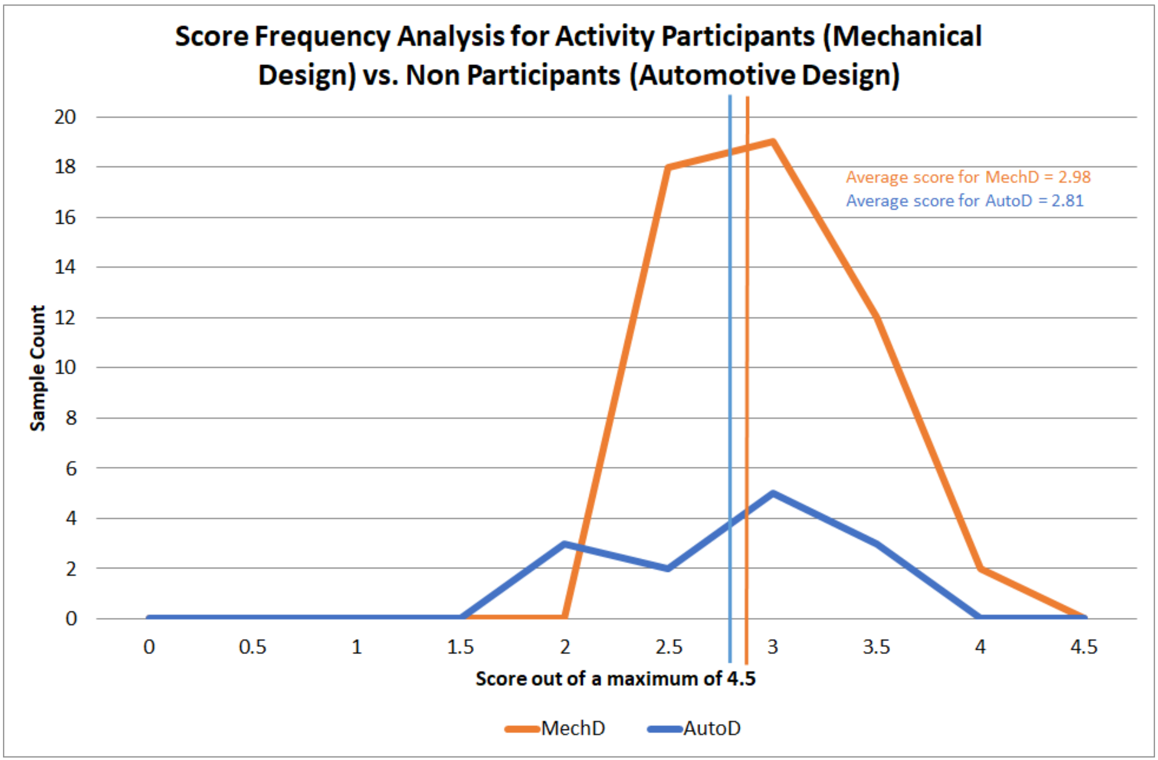


Figure 6.12: Chart 11, Score frequency Charts illustrating the differences in performance between activity participants (students on the Mechanical Design module) and non-participants (consisting primarily of students on the Automotive Design module and some from Mechanical Design)

The vertical lines in Figure 6.12, Chart 11 represent the difference in score (out of 4.5) for the element of assessment that relates to the learning outcomes of the activity. The average score in this element for participants was 2.98/4.5 (66%) compared to 2.81/4.5 (62%) for non-participants.

6.16. Summary of addressing research questions and conclusions

This case example reports on a studio based GBL/ABL activity and presented the results of the findings in the form of qualitative feedback received from learners as well as quantitative results obtained from levels of attainment and performance in the modules where GBL/ABL activity was used. GBL/ABL learning enabled the observation of the effects on students' performance in a simple in-class game.

It was established that the students performed better in the subjects which build on the knowledge, skills and understanding acquired in GBL/ABL, such as an end of year detailed design project. There was a clear benefit of engaging the students in a collaborative learning activity which was evident from individual assessment scores. Through individual and instructor questions and answers, they “filled” knowledge gaps, leading to a successful completion of design tasks.

Mostly, the students were not hindered by participating in a group activity, and benefited from a competitive environment gauging their performance against their peers, and competing for the top scoring place in the ranking.

Students who ranked within the top half of collaborating groups in the GBL/ABL activity had also performed better on an individual basis at the end of year assessment. However, this was considered to be bias because such students would inevitably perform better during the game as well as in their final individual assessment. This therefore called for further quantitative analysis which had revealed that even groups consisting of either two or three participants and of mixed ability and level of background knowledge, had still performed individually better.

As a result of GBL/ABL it has emerged that learners acquired knowledge, skills and abilities according to the learning outcomes for the module, whilst also experienced an enjoyable learning activity and hence requested further collaborative learning sessions.

Based on the evidence acquired it can be concluded that a blended learning approach to teaching and learning can produce a powerful set of tools for Mechanical Engineering education that improves motivation, engagement and attainment of students on undergraduate engineering courses.

Two of the other research questions were as follows:

- Did the activity serve as an effective means of formative self-assessment, to gauge standards of students against their peers?
- Was the activity enjoyable and was attainment improved as a result?

These have been addressed as part of the section in this chapter in which qualitative analysis of the student feedback questionnaires is considered.

It can be concluded that the research questions have been clarified satisfactorily in the research study.

We have addressed a challenge of providing a robust education to engineering undergraduate students and equipping them with the skills and knowledge for a real world environment through motivating and engaging them as learners. The researcher's approach was one of GBL and ABL which require collaborative learning.

This approach has led to the University's recognition of this innovative approach to teaching and learning by awarding "The Teaching Excellence Prize" – best course team for student outcomes (student cohort exceeding 100 students) during the 17/18 academic year.

6.17. Summary

In this chapter we have introduced a GBL activity that forms another case study for qualitative and quantitative analysis, a novel aspect of the research. The activity takes a holistic approach in supporting and reinforcing knowledge acquired within Mechanical and Automotive Design modules on an undergraduate programme. It reports on students' ability to engage in hands-on practical collaborative learning, utilising existing skills in order to collectively share and reinforce knowledge.

Chapter 7 – Summary of Analysis of Case Study Results and Conclusions

7.1 Critical reflection on the findings and actions arising from Case Study 1

This case study's teaching intervention was based on a Flipped Learning Classroom.

The principal findings from this study, which arose as a recommendation from the initial study, were:

- More sessions were to be delivered using the flipped classroom approach
- Clarification needed whether students had performed better in assessment despite greater engagement, participation and an enhanced learning experience through the interventions.
- Larger set of data samples needed to validate changes in assessment performance (specifically for certain topics).

In case study 1 (chapter 4) improvement in the student learning experience was reported, however, with insignificant initial improvement in examination performance. This was in response to the 7 (out of a total of 80) questions included in the end of year examination. The difference in average score for all students between the seven questions covered by FL and the average score for the other 73 questions was less than 2%. This was insufficient for us to conclude that the method of delivery was performance enhancing for learners.

In a subsequent year I had identified and categorised all topics that were to be covered during the lecture programme. These consisted of nine topics as previously listed in chapter 4. Suitable AV material was identified for FL delivery. A summary of the interventions in delivery was as follows:

- ➢ Recommending prior viewing and directing students ahead of a scheduled class
- ➢ Initial in-class discussion on the topic with a more dialogic form of delivery which included a set of PowerPoint slides
- ➢ A carefully selected DVD of approximately 20 minutes duration on the topic

- Poll voting multiple choice questions using EVS with either voting pads of smartphones using the TurningPoint app, which the students had downloaded prior
- Brief review discussion based on the response to polling.

There were four topics for FL.

The topics would account for just over half (42) of the 80 examination questions. The interventions were therefore applied more rigorously than in the previous experiment.

7.2 Summary of results of case 1

The exam results for each subject topic were analysed and these are displayed with comments in the Charts contained in chapter 4.

Figure 7.1 shows the average scores for each examined topic. The overall average score is represented by the straight horizontal line. For this particular year the average exam score was 48%. This appears low which is reflective of the difficulty students have with such a subject that is completely new to them and also the volume of material.

To compare this score with previous years' results would be futile and fraught as I would have been dealing with a different cohort of students (a point also identified by Rossiter, 2011).

It is worth stating that the overall student year end score for the module is significantly higher than this because of higher scores achieved during the practical workshop practice attended by the students in which they have the opportunity to be graded well based on practical competencies (skills).

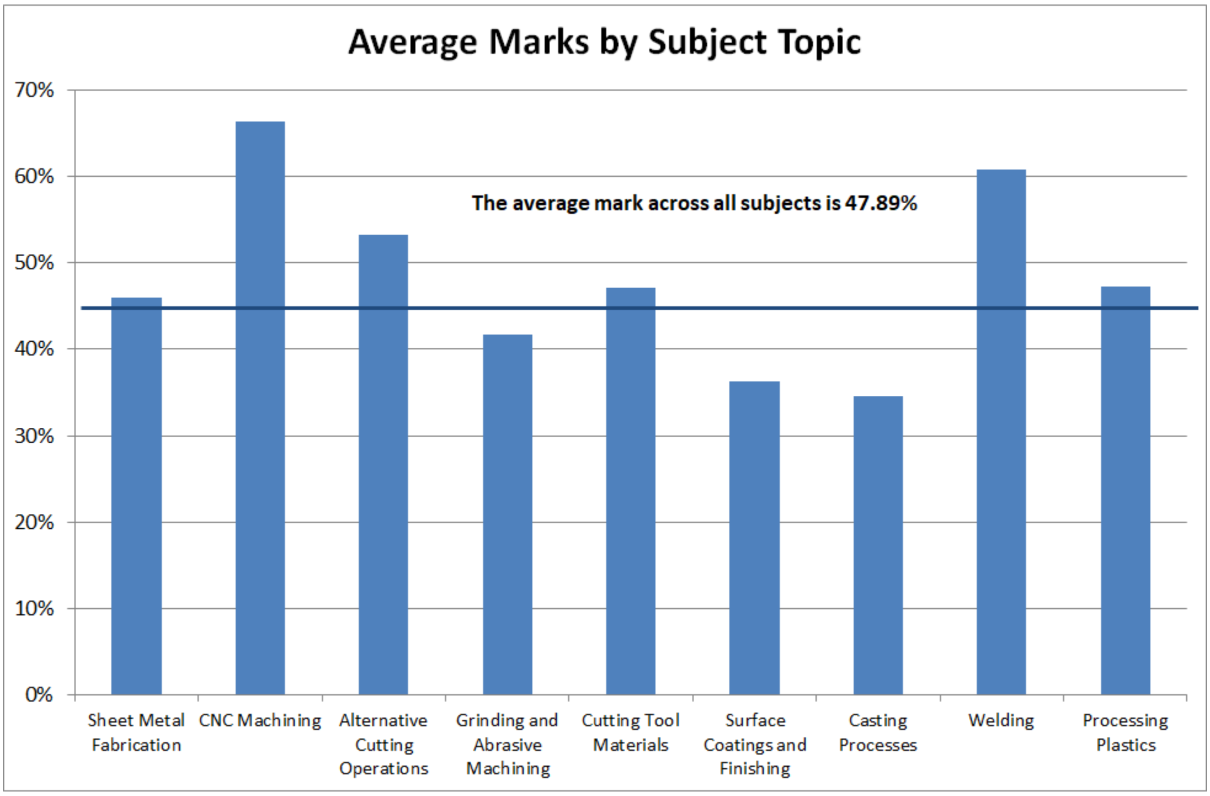


Figure 7.1: Shows the average scores by topic and the overall average score for the entire exam

We had concerns as to why students scored low in certain topics.

Only one was delivered using the FL method of delivery and this was, casting processes, which had the lowest average of all topics. I therefore explored the exam questions presented to the students and identify the lowest scoring that is attributed to bringing down the average score and tried understand it.

Three out of the nine questions for this topic (casting processes) had an average score of below 20%. This had lowered the overall score for the cohort, considerably. The questions have been detailed in chapter 4.

With reference to question 75 on an exam paper, there were four answers offered to candidates. The question was with reference to the casting process for metals. The correct answer to the question was option B and only 13% of students had determined this. The question required detailed knowledge of sand casting to a level that was not covered in the AV material but only acquired through the notes and then deduced based on known facts. This would indicate that the majority of learners simply skim the surface and do not delve into detail required through reading and probing.

Similar issues were identified with the other two, low scoring topics. Three out of the ten questions in surface coating and finishing had an average score of below 20%. This had lowered the overall score for the cohort, for this topic, considerably.

Our next analysis was to consider a comparison in scores between questions associated with topics in which I had introduced interventions using AV and the FL approach. The Chart shown in figure 7.2 illustrates the scores by topic for each of the two types of delivery (with and without interventions). It also shows the overall average score for each type of delivery.

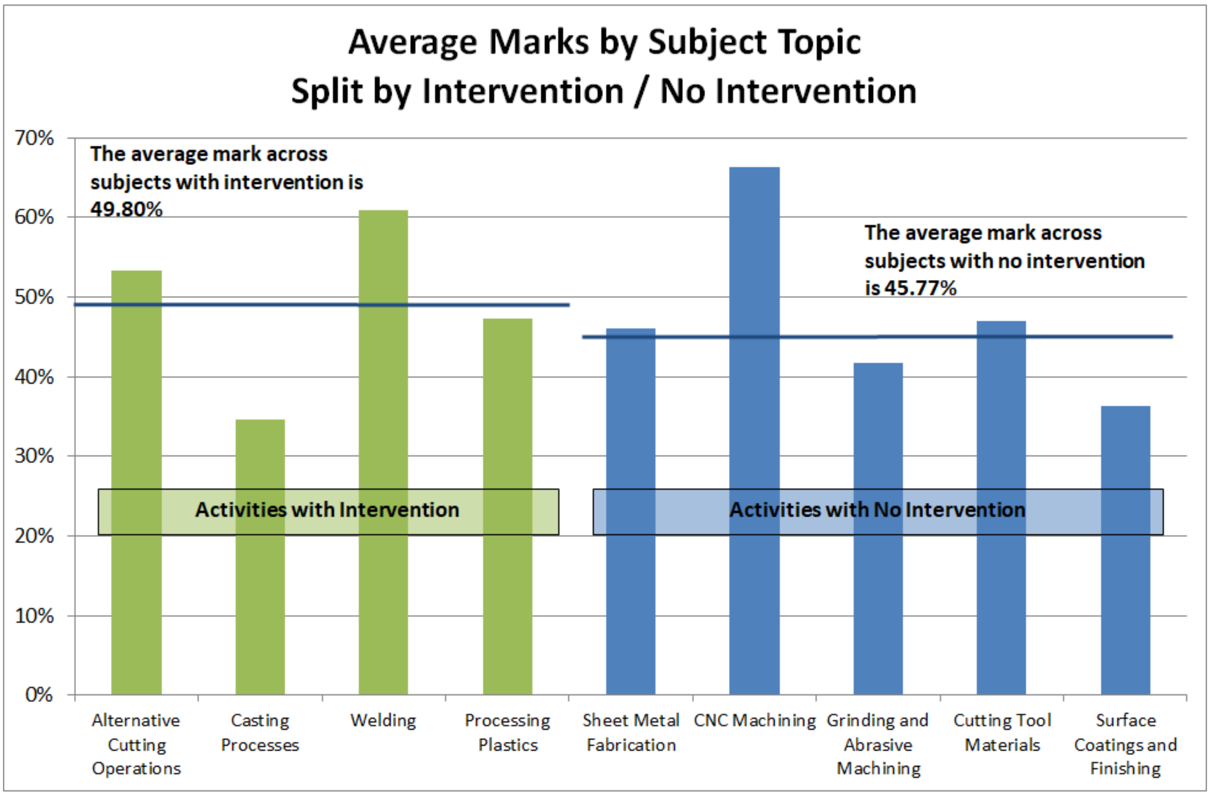


Figure 7.2: Shows the average scores for each type of delivery method. The four columns to the left have interventions in delivery whilst the five columns to the right have no interventions

With reference to the Chart shown in figure 7.2 I was able to hypothesize. The first was that despite the method of delivery there is a significant low scoring topic for each. Within the green range of columns, where there were interventions, casting processes had lowered the overall average score. Within blue range of columns, with no interventions, surface coatings and finishing had lowered the overall average score. The reasons for these low scores were identified earlier and put down to lack of in-depth detailed knowledge across the entire topic. This can also lead us to assume that lack of detailed knowledge leads students to think that there is ambiguity in certain questions (in that there are two possible correct answers).

Another hypothesis is that despite each of the two methods of delivery having low scoring topics, where interventions have been applied, the overall score across all topics is 4% higher (50% Vs 46%). Improvements of at least this order are also reported in Freeman et al., (2014), who carried out a meta-analysis of active learning in STEM subjects, which further substantiates the result.

In the final analysis I explored the results in order to try to identify the common factor that links the highest scoring topics.

The three highest scoring topics in order of highest to lowest are

1. CNC Machining (5 questions, average score 67%)
2. Welding techniques (10 questions, average score, 61%)
3. Alternative cutting processes (11 questions, average score, 54%).

Figure 7.3 illustrates a Chart in which all the examined subject topics are divided into two categories. The first category is represented by the green columns and represents the two topics in which learners had gained some experiential learning though workshop-based practice. This was skills based and entailed two complete and separate days of attendance for each topic, (four days, in total, within a workshop environment) at a technical college. No detailed knowledge was provided during the practical sessions. Blue columns represent all the remaining subjects without experiential learning. The difference between the two, in terms of examination performance, is 19%. This is quite a significant difference which can draw us to a safe conclusion that despite the skills based learning outcomes of workshop practice; it motivates learners for greater inquisition of topic detailed knowledge. Perhaps this is because they are able to see the relevance of the topic in a practical context.

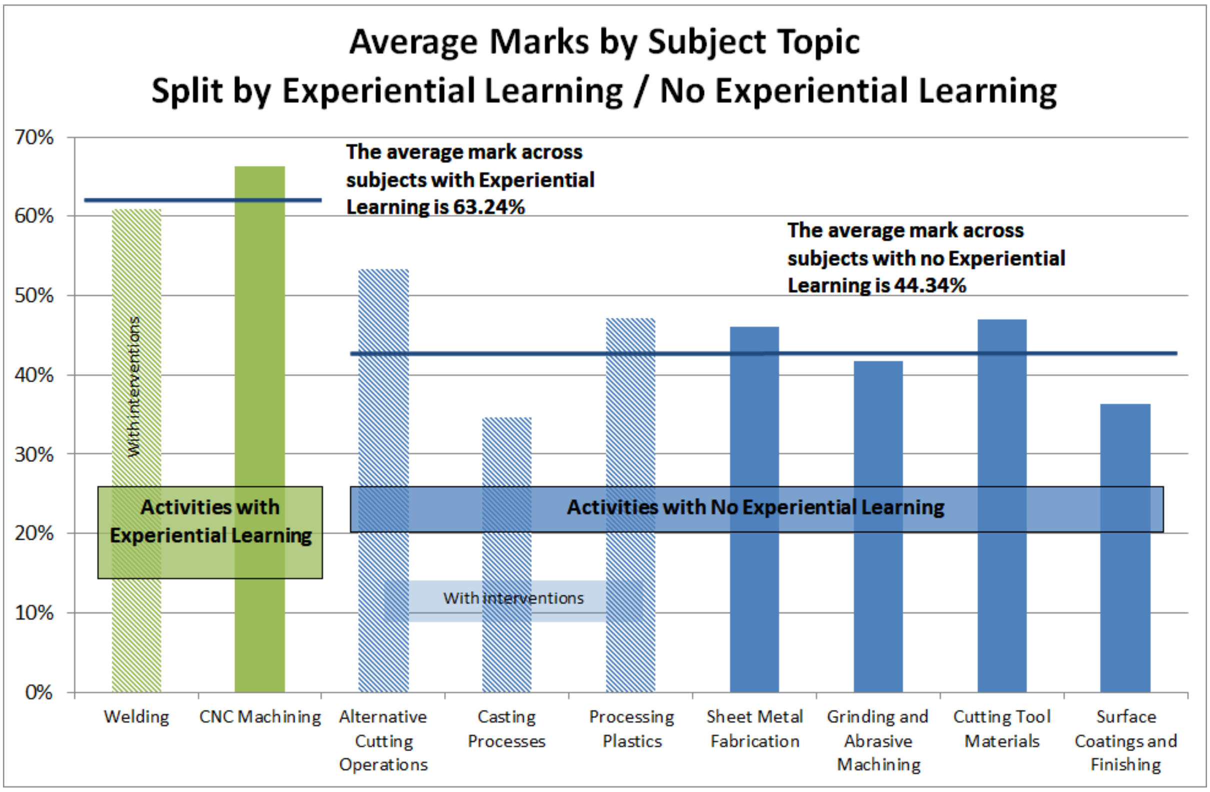


Figure 7.3: Illustrates that experiential learning combined with class-based interventions has made a significant difference in the overall cognition and higher order learning, as is evident from the green columns

Interventions in class delivery method that utilises the Flipped Learning method has helped in improved learning and assessment results. It has certainly enhanced the student learning experience. Experiential learning combined with class-based interventions has made a significant difference in the overall cognition and higher order learning, as is evident from the green columns in figure 7.3. Within this Chart all the examined subject topics are divided into two categories. In green are the two topics in which students have gained from experiential learning. The blue columns represent all the examined subject topics with no experiential learning. The shaded columns (both in green and blue), represent the topics delivered with interventions for enhanced learning.

7.3 Conclusion that can be drawn following analysis of case 1

Some topics are more interesting than others in that they capture the imagination of learners and are more intriguing to them. Alternative cutting processes is one such topic as it includes machining with lasers, abrasive water jets and sparks (in spark eroding).

The younger learner is not concerned with in-depth detail and breadth of subject knowledge. This takes time and is deemed to be futile because information can be obtained just-in-time as and when needed on the internet. Such knowledge requires dedicated time; something that young learners are not accustomed to and not prepared to do in a fast paced world of instant information (Prensky, 2001).

Experiential learning is invaluable in complementing subject knowledge despite the learning outcomes being skills based. It promotes deeper understanding and acts as a catalyst for deeper knowledge and understanding from more common class-based delivery, irrespective of whether delivery is dialogic or didactic based. A good example of where this works well is in the training of medical practitioners (combining practical hospital based work and class-based learning). There are several other examples of this (such as dentistry and podiatry). Higher Education in Engineering goes part way to meeting this requirement but falls short of a more rigorous stance. This may be partly due to economics whilst in medical applications the consequences of lack of knowledge with combined skills are regarded as being more critical (Barrows, 1986, Perrenet et al., 2000, Beaty, 2003)).

The improved results that have arisen from action learning (experiential workshop practice) combined with active learning (flipped classroom delivery) support the knowledge integration framework (KIE) (Linn, 2000) as reviewed in chapter 2. According to this framework learners construct knowledge by continuous evaluation, reviewing, refining and developing ideas received from training and observations. The framework describes knowledge integration as a dynamic process of linking ideas and theories in order to rationalise concepts. Observations are something that was actively encouraged during delivery.

A blended learning approach to teaching and learning that utilises the Flipped Classroom approach can yield improvement in learning and higher order thinking but must not be considered in isolation from other delivery frameworks. It must be periodically reviewed to a detailed level in order to consider shortcomings which can lead to further enhancements in delivery. This methodology is also compliant to the action research spiral (Zuber-Skerritt, 2001) which was reviewed in chapter 2 and with other AR methodologies which pursue change through understanding by action and critical reflection and later by refinement of methods, data and interpretation through reiteration (Dick, 1991).

The Flipped Classroom delivery enhances the student learning experience resulting in a greater class engagement. In the case study learners have expressed great satisfaction in this method. The researcher has made a case here that the benefits, in terms of assessment performance, are disproportionate to the hype. But they do enhance the learning experience which is largely what today's fee paying learner expects.

7.4 Introduction to case study 2

Chapter 5 documents the second case study which aimed to evaluate the effectiveness of Games-based Learning as a tool for teaching and learning in CAD. As in case study 1 sought to achieve outcomes of research that were both qualitative and quantitative. A game was devised based on a resin puzzle cube and had listed several research questions to address.

7.5 Method applied to case study 2

As in case 1 qualitative feedback was sought from a list of questions that formed a questionnaire, directed to learners. Furthermore, there was an element of assessment as part of the module and sought to establish changes in assessment performance as a consequence to the intervention through the use of gamification. There was also an element of student collaborative learning as part of the activity which the researcher wanted to draw conclusions from.

7.5.1 Summary of results to case 2

The qualitative results from the student feedback questionnaire are overall very positive as is evident from the Charts presented in chapter 5. 87% of learners thought that more classroom sessions should be delivered in this manner and 82% considered the activity to be interesting and relevant to their course. As the question regarding improved learning (evident through assessment) remained post-activity, I evaluated performance against student participation in the activity. Figure 7.4 (also previously presented in chapter 5) is testimony to the positive effect of activity to student learning. In this Chart the researcher was able to see a graphical representation of results showing improved overall performance by game participants along with the students' profiles in average tariff points at entry in to Higher Education. The red line represents the tariff points at entry of classified groups of students (participants, non-participants, non-completers). The vertical scale to the right indicates average tariff points at entry whilst the vertical scale to the left represents end of year assessment score in subject matter.

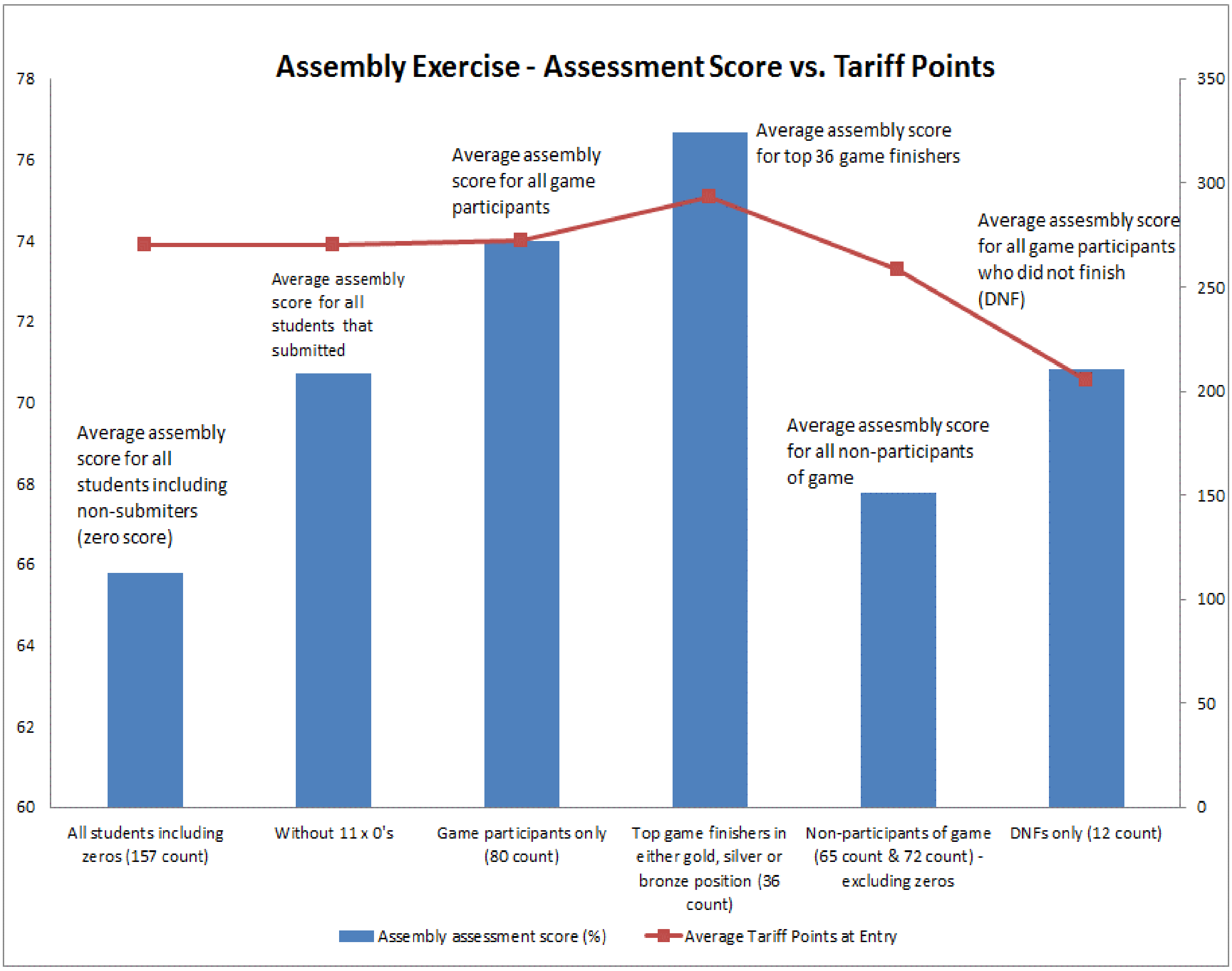


Figure 7.4: Graphical representation of results showing improved overall performance by game participants. The vertical (y-axis) to the left shows average assessment scores whilst the vertical axis to the right shows average tariff points at entry to HE for each group

7.5.2 Conclusion that can be drawn following analysis of case 2

Both the qualitative and quantitative results of this case study were overall very positive. This is evident from both the evaluated student feedback, engagement, participation and improved performance in assessment. The results presented as part of chapter 5 overwhelmingly support further activity based learning (ABL) and gamification in particular. It was apparent from this activity that students would welcome activities that introduce real, engineering related artefacts. This would pose a further challenge in future work, though partly satisfied and described in chapter 5.

7.6 Introduction to case study 3

Chapter 6 documents the third case study in which the researcher introduced several active learning techniques (ABL, GBL and Collaborative Learning) within a single studio based activity for enhance teaching and learning in Mechanical Design. The approach was holistic and as in case 2 I sought to achieve research outcomes that were both qualitative and quantitative.

7.6.1 Method applied to case study 3

As in previous cases I established qualitative feedback from a list of questions that formed a questionnaire, directed to learners. There was also an element of assessment as part of the module which assisted us in establishing changes in assessment performance and quantifying these, consequently of the interventions. There was an element of student collaborative learning as part of the activity, from which I sought to draw conclusions.

7.6.2 Summary of results to case 3

The qualitative results of the survey revealed that was an overall majority consensus that the activity was both interesting, absorbing and relevant to the module and course (90%). The full set of these results are presented in the form of Charts within chapter 6. From the Chart presented in chapter 6 and replicated below as figure 7.5 it can be concluded that active learning in this case has resulted in improved assessment scores. Even though this was a small improvement, it was commensurate with the weighting allocated to a small aspect of assessment (attention to detail design). The average score in this element for participants was 4% greater than non-participants (66% versus 62%).

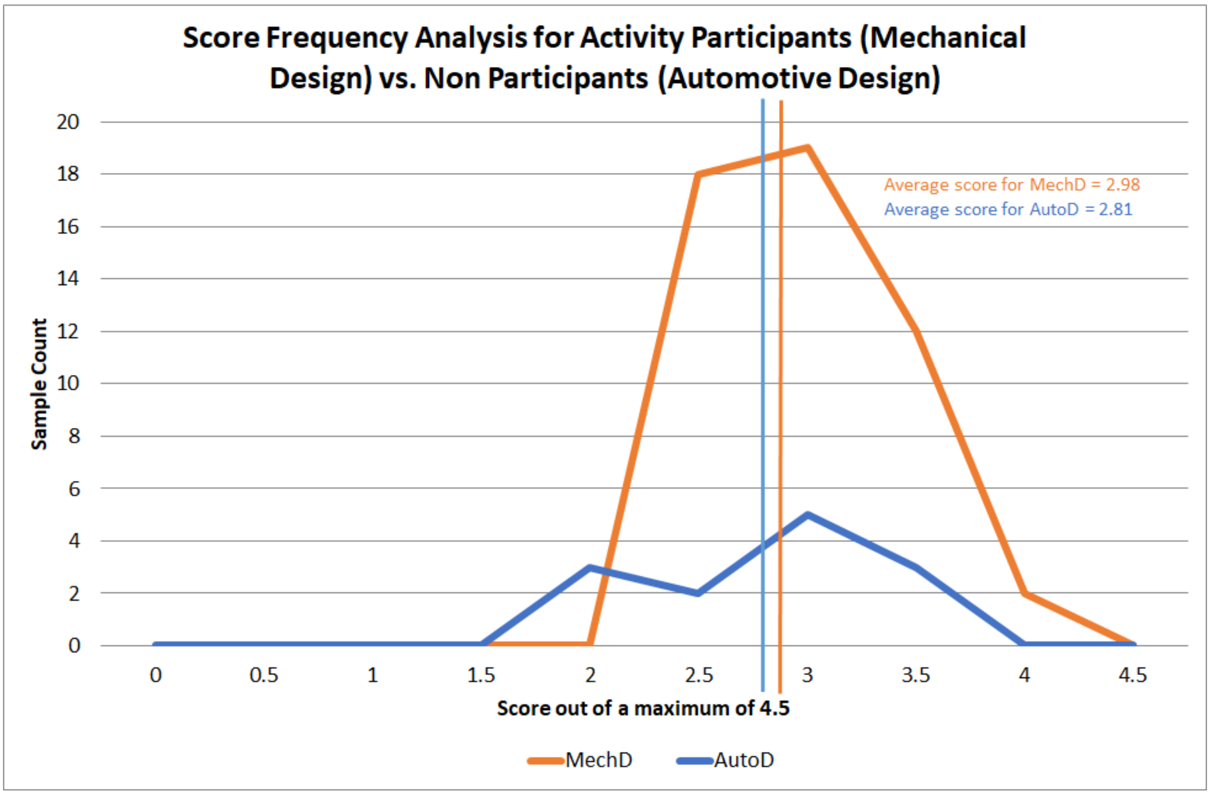


Figure 7.5: Score frequency Charts illustrating the differences in performance between activity participants (students on the Mechanical Design module) and non-participants (consisting primarily of students on the Automotive Design module and some from Mechanical Design)

7.6.3 Conclusion drawn following analysis of case 3

The breakdown of entry qualifications on to the Engineering Bachelors programme indicates that a large proportion of entrants arrive with vocational BTEC qualifications. This would indicate to us that such learners prefer and benefit to greater extent from active learning as described in case 3. Because of GBL/ABL, I we are able to conclude that students were able to acquire knowledge, skills and abilities in accordance to the learning outcomes of the module in an engaging manner. The learner experience had prompted the desire for more active and collaborative learning sessions. Based on the evidence it was concluded that a blended learning approach to teaching and learning could produce a powerful set of tools for Mechanical Engineering education that improves motivation, engagement and attainment of students on undergraduate engineering courses.

7.7 Critical reflection across all three case studies – addressing the research questions

The common thread across all case studies was active and blended learning. Could interventions that combined these in Mechanical Engineering education enhance teaching and learning? The conclusions have clearly indicated that they can, across all three case studies.

From the case studies the researcher has shown that learners absorb information better if it is delivered in piecemeal measures in a structured and constructive manner. The introduction of EVS within class sessions (case 1) enhanced engagement, provided formative feedback to students (as to their level of understanding in specific subjects) and allowed the tutor to gauge the level of knowledge gained. It also allowed for reflection in the covered material. This accompanied with flipped classroom delivery involving time-limited audio-visual material had further enhanced learning. More fundamentally, I have shown through this research that a mixture of class-based delivery and experiential learning had resulted in higher order learning which was reflected in improved assessment results within some topics of the module. Higher order learning was common to all three case studies as was greater fun in learning thus enhancing the learner experience.

Another common finding across the case studies was on the value and effectiveness of Integrated Concurrent Engineering Education. If students gain knowledge and understanding within individual subjects, they are too often unable to put the information within the context of the wider world of engineering and technology. They are therefore acquiring fragmented information outside of context and therefore unable to recognise its importance. Evidence of improvement in this was evident across all three case studies to some degree. More of this is required in engineering education (i.e. how is good design possible without consideration of the processes of manufacturing and available materials?).

We also evaluated the merits of Action/activity Based Learning within all three case studies within the same subject area (Mechanical Engineering). Improvements were quantified in assessment results whilst also obtaining qualitative results through feedback from students who reported a more enhanced learning experience. This was a small element in which the phenomenography methodology was apparent within the research case studies.

Two of three of the case studies had shown the effectiveness of GBL when introduced as part of learning activities for reinforcement of knowledge. This was therefore proven to be a suitable method of delivery, assessment and feedback for mechanical engineering subjects.

Another aspect of the research was concerned with collaborative learning. This played an important role in all cases. Collaborative learning worked for most students, but not all. I identified that it is less effective amongst weaker students who may struggle with the pace of learning within classes therefore require greater nurturing on an individual basis and at a slower pace than the main group. It is also less effective with students whose social and interpersonal skills are limited and less developed (as compared with their peers). However, collaborative work develops such skills. I also identified dissatisfaction amongst more able learners placed within groups for collaborative learning. This was due to being placed (without choice) amongst less able and enthusiastic individuals who were not as motivated, though this was not entirely definitive as I was unable to identify students who responded negatively or their reason for doing so. This is something identified for future study.

We also established that regardless of the level of entry qualification, ABL enhances learning to a greater extent (from an individual's base level) for greater 'added value' as compared with traditional didactic delivery. This was found to be the case for all learners regardless of type of learner and their previous experience.

Across all of the cases studies I was able to witness how the younger learner is not concerned with in-depth detail and breadth of subject knowledge as this takes time and is deemed to be futile. Information can be obtained at hock when required from an immense pool of resources available on-line. As Prensky, (2001) identified, in-depth knowledge requires dedicated time and young learners are not accustomed to doing this in a fast paced world of instant information. They are however more receptive to being engaged in active learning. This is a reflection of changes in learning culture amongst younger learners.

We viewed e-Learning from a different perspective than the work reviewed (which appears to take a rigid line of 'all or nothing' approach). The research has shown that e-Learning does not have to be entirely about asynchronous on-line learning. The case studies utilised information finding on the web, educational audio visual material and a Virtual Learning Environment. The essential ingredient in all three was social interaction and creativity in formulating the activities. Transforming engineering education does not therefore necessitate a daunting training and personal development process of facilitators.

7.8 Summary

In this chapter, the researcher has summarised the results of the case studies from previous chapters. The results are presented in detail in individual chapters. I have refrained from duplicating the results and conclusions in their fullness as they have already been previously presented in their original context. This chapter briefly concludes on the results previously presented, and collates the results into an overarching outcome of the individual case studies. It finally reports on how the research questions are collectively answered through all three case studies and identifies the common points across them.

Chapter 8 – Conclusion

Revisiting the research aims, objectives and questions from Chapter One, this chapter considers what has been learned about Active Learning in teaching and learning and identifies the common thread across three case studies. It summarises the findings linked to the original aims and objectives and the research questions and identifies the novel content and achievement of this work (novel aspects), and how these new bricks (Wellington, 2000) add to the wall of knowledge on the practices of engineering education.

8.1 Overview of original aims and objectives

In chapter 1 the researcher set out the aim of the investigation which was to develop an optimum blending of e-learning interventions with traditional teaching systems to obtain maximum teaching-learning effectiveness. Of the interventions, GBL and Flipped Learning would form part of the research investigation, utilising e-Learning as part of the process.

The researcher sought to build on Bloom's Taxonomy in order to deepen understanding, by quantifiable means, of teaching and learning in engineering and technology. The researcher wanted to utilise e-learning techniques in the process.

The researcher sought to enhance the Teaching and Learning process by bridging the gap between learner expectations and the educator in the general subject area of Engineering and quantify the Teaching and Learning effectiveness.

In summary, the researcher wanted:

1. To enhance the level of Teaching and Learning provision
2. To develop suitable interventions to improve teaching effectiveness
3. To quantify the teaching and learning effectiveness.

With reference to the first research objective-to enhance the level of Teaching and Learning provision, the following three sub-objectives were outlined:

1i.To identify details of existing frameworks in teaching and learning

1ii To identify the application of theoretical framework to ascertain Teaching and Learning effectiveness

1iii To develop an improved theoretical framework to Teaching and Learning in CAD/CAM and Engineering Design.

With reference to the second research objective- to develop suitable interventions to improve teaching effectiveness, the following three sub-objectives were identified:

2i Applications of Games Based Learning in the Teaching and Learning process

2ii Application of flipped learning approaches in the Teaching and Learning process

2iii Application of integrated Games Based Learning, Flipped learning techniques and Activity Based Learning.

With reference to the third research objective- to quantify the teaching and learning effectiveness, the two sub-objectives identified below have utilised quantitative techniques. This clearly presents a novel aspect of this research work, as is evident from the literature review:

3i Evaluation of Games Based Learning and Flipped Learning interventions in Teaching and Learning effectiveness

3ii The development of qualitative model to reflect incremental learning enhancement in CAD/CAM and associated areas such as Manufacturing Technology and Design.

8.2 Addressing the research questions

We defined several research questions from the outset of this research and in the course of the case examples, identified further questions which were subsequently addressed.

The research questions presented following the literature review are reiterated as follows:

- Can the researcher quantify the educational benefits of using Electronic Voting Systems (EVS) and express these in terms of improved student learning?
- Do EVSs enhance the student learning experience?
- Are learners able to achieve improved examination results in subjects delivered by a revised method of the Flipped Classroom and can they subsequently achieve a higher level of learning?
- Does the flipped classroom approach enhance the learning experience, through better engagement with the students, compared to conventional classroom-based learning?

In the first case study, covered comprehensively in chapter 4, the researcher reported and concluded very positively on the advantages of using EVS and how these enhanced the student learning experience. It also reported improved assessment results in subjects, which were associated with a combination of flipped learning, discussion based class setting using EVS and especially enhancement through practical workshop based experiential learning. Learners had informed us of a more enjoyable learning experience and the quantified results had verified improvement in performance. In subjects where learners had benefited from practical workshop practice, the improvement in performance was significant. In subjects delivered with interventions but without practical experience, there was also a gain but not as significant.

- Is Action Based Learning (ABL) a suitable method of delivery for Mechanical Engineering subjects?
- Is GBL a suitable method of delivery, assessing and feedback of mechanical engineering subjects?
- Would a combination (Blended learning techniques) be deemed more suitable for delivery of Mechanical Engineering subjects?

The case studies covered in chapters 5 and 6 were reported in detail and the results affirm positive answers to the latter three research questions. Presented was a strong case for ABL as a suitable method of delivery for Mechanical Engineering subjects. Learners had demonstrated a greater level of engagement and a deeper level of understanding.

As regards to GBL, it is ascertained that it can be successfully integrated as part delivery, assessment and feedback in Mechanical Engineering subjects, provided that the researcher does not lose sight of learning outcomes and the pedagogical reasoning behind the GBL activity. It is therefore important that the design of such instructional games should differ from pure entertaining games in that they are designed intentionally to facilitate achievement of specific learning goals and objectives as emphasised in the literature search (Himuri and Stapleton, 2010). This achievement was evident through the second and third case studies covered in chapters 5 and 6. The case studies demonstrate that Games Based Learning can be developed such that they can embody established learning principles, theories and models, yet utilise digital devices.

Combined, all of the case studies present a solid case for Blended Learning Techniques in Mechanical Engineering Education. The possibilities of such blended techniques are endless with scope for more exciting delivery in light of ever changing technological tools available to the teaching practitioner or facilitator.

One of the early research questions was whether the researcher was able to improve the effectiveness of teaching and learning whilst delivering engineering and technology subjects through varied and blended teaching and e-learning techniques that will encourage students to learn by greater involvement, stimulation and inquisitiveness. A positive improvement in the effectiveness of T&L has been demonstrated in all the case examples. A varied blend of delivery techniques works well. The optimum balance of applying such techniques is subject to further work.

We also raised the question as to whether it was possible to develop suitable quantitative tools to quantify micro-learning effectiveness. This has been addressed successfully through the three case studies, described in chapters 4, 5 and 6. Identifying and understanding the learning styles of a small number (a minority) of individual learners is subject to further work. As an example, certain learners do not thrive in group activities where collaborative learning is required. This therefore is subject to future research.

In chapter 1 the researcher questioned whether didactic teaching and in particular the traditional lecture has exceeded its time as a form of delivery. This question was in reference to a limited number of educational institutions who have made a paradigm shift in delivery using only project and case based learning with examinations limited to a maximum of 20% of overall course assessment. The research shows that a blend of techniques, including some traditional delivery with greater interaction, works effectively. I have identified that no single techniques consistently work to best effect with a group of learners, therefore a blend of techniques need to be considered in accordance to the learner level, learner profile, learning style and desired learning outcomes. The nature of the subject delivered must also be a prime consideration.

As part of the review the researcher considered the work of (Bates and Galloway, 2012) who reported on an example of Active Learning for a year 1 mathematics based, introductory physics course. Their study was based at a different University and for a different subject area to ours. The cases relate to a different subject area and one that benefits greatly from AV impact as well as discussion and illustration.

Another fundamental difference is the nature of the learner. It has been concluded that the same response could not be expected from own learners as those from a University offering more academic rather than vocational courses. The revised methods which are described in the case studies are better suited to the learners to which they are directed. It can be concluded that development of hybrid teaching strategies which are based on existing frameworks and theories (such as Laurillard's and Kobl's) but with specific application to Engineering and Technology subjects bring about improvements in teaching and learning in qualitative and quantitative ways. The researcher has concluded that there is an association between performance (through better understanding) in subjects delivered by conventional didactic classroom delivery (passive learning) and those delivered by active learning in class. The research therefore concludes that Action Based Learning (ABL) is a more suitable method of delivery for Mechanical Engineering subjects. This also includes Games Based Learning (GBL) as well as blended learning techniques. The creative application of interventions for enhanced Teaching and Learning in Engineering and Technology subjects should therefore combine active learning techniques, which include e-Learning and Gamification along with their ongoing evaluation in accordance to the spiral of Action Research (Zuber-Skerritt, 2001).

8.3 Novelty of this work and closing the knowledge gaps

The research conducted was focussed on mechanical engineering discipline and produced frameworks and methodology that can be adopted by other Higher Education Institutions to improve the delivery and student achievement in Teaching and Learning Mechanical Engineering subjects.

It is strongly anticipated that this work will benefit Teaching and Learning in other engineering disciplines adapting Flipped-classroom, Games Based Learning, e-learning, Activity Based Learning and the application of an Integrated Concurrent Engineering Education approach to engineering subjects. The influence, to date, of this work is evident by the access to the published case studies contained within the dissertation and that form chapters 4, 5, and 6.

From the literature review in chapter 3 it became evident that there is a distinct lack of empirical data of the pedagogical benefits of educational games despite the large volume of publications that exist on gamification (Markopoulos et al., 2015). The researcher has addressed this research question in two of the case studies (detailed in chapters 5 and 6) where gamification was introduced as part of the activities.

As part of the review it was identified that the need for a stronger research agenda is required to be driven by theoretical and empirical research (Haghighi, 2005). This research reduces that shortfall.

Gaps in undergraduate engineering education through Action Research were identified (Jensen, 2015). It was reported earlier that AR is still relatively rare in engineering education research (Case and Light, 2011). The core methodology applied in this Engineering Education research has been AR yet it has been combined with grounded theory methodology in order to quantify the outcomes of the interventions. This is another novel aspect of the research. The work has therefore designed, developed, implemented and evaluated through analysis, blended learning based on Action Research.

Chapter 1 considered the term 'Engineering Learning Mechanisms' which refers to the process of developing knowledge and competencies in context for engineering learners. This was coined from Lave's Situated Learning framework. Situated learning is a general theory of knowledge acquisition and developed on the belief that learning normally occurs as a function of activity, context and culture. It includes situated classroom learning where knowledge is frequently 'given' as abstract and out of context. A novel aspect of this research is that it applies Lave's framework in the context of engineering and technology-based learning activities, focusing on problem solving skills. It has been based on the principles that:

1. Knowledge needs to be presented in an authentic context, i.e., settings and applications that would normally involve that knowledge.
2. Learning requires social interaction and collaboration.

We have demonstrated these principles in all of the case studies. Figure 3.1 (in chapter 3) diagrammatically illustrates situated learning.

Chapter 1 considered a comprehensive review by Johri and Olds, (2014) of Cambridge Handbook of Engineering Education Research (known as CHEER) which was published in 2014. The reviewers identified missing topics which included topics on motivation, team work and collaboration. Having considered these topics as part of the research, was in recognition of the shortfall of work in these areas.

(Johri and Olds, 2014) also identify that there is insufficient knowledge generated that can be used by engineering education practitioners, but rather by engineering education researchers. The research which has been based on AR and pragmatic in its nature lends itself to being adapted to a wide range of engineering subjects, another novel aspect of the research. (Johri and Olds, 2014) identify the lack of conversion of conference into more prestigious journal articles. I have addressed this shortfall through the publications that resulted as outcomes from this research.

As part of the aims and objectives it was stated that the research sought to enhance the Teaching and Learning process in engineering education by bridging the gap between learner expectations and the educator, for greater effectiveness. I have achieved this as it is evident through the case examples by utilising learner feedback. I have thus combined qualitative along with quantitative methods, another novel aspect of the research, especially as it has been applied within subjects in Manufacturing Technology and Design.

Through reflective Teaching and Learning this research has become broader than simply applying e-learning tools for an enhanced student centred learning experience. With its specific aims it led to quantifiable novel aspects in teaching and learning in CAD/CAM and closely associated subjects. The reason for this is that it has become evident through reflective Teaching and Learning that no single technique works to best effect with a group of learners, therefore a blend of techniques needs to be considered in accordance to the Learner level and desired Learning Outcomes and the nature of the subject delivered.

In the case examples detailed within chapters 5 and 6 it was demonstrated how a more holistic approach to engineering education may be taken. I have referred to this as Integrated Concurrent Engineering Education (ICEE). This concept originally stemmed from earlier work (Sherwin and Mavromihales, 1999).

8.4 Contribution to knowledge

1. In all case studies, I have provided both qualitative and quantitative data resulting from the analysis. This provided the proof that with the appropriate interventions,

active learning enhances teaching and learning in engineering and technology subjects, particularly in mechanical engineering education. This was something that was originally questioned following the literature review (Freeman et al., 2010) – See research questions

2. With appropriate structured delivery, I have shown that EVS work as an effective means of reflective learning, enhanced engagement and formative feedback. The extent to which they improve teaching and learning is dependent on a mix of interventions including experiential learning.

3. Through two of the case studies, I have shown that GBL offers a suitable method of delivery in mechanical engineering education, provided that it is not overused, the learning outcomes are addressed and there is pedagogical reasoning behind the activity. With quantification of the results, the application of GBL I have contributed to new knowledge. It is therefore a suitable method of delivery.

4. A contribution to knowledge, without doubt throughout the case studies, was that a blend of techniques is suitable for mechanical engineering education subjects. I have also identified that no single technique, works to best effect with a group of learners. A blend of techniques must be considered.

5. The empirical data provided in each of the case studies is testimony to the novelty of this work and its contribution to knowledge (Olds et al., 2005, 2012).

6. I have applied Action Research in engineering teaching practice as the core methodology. This, in itself, contributes to a novel aspect of this research. This was a gap in undergraduate engineering education as also identified by Jensen, (2015) and Case and Light, (2011). Johri and Olds, (2014) identified the lack of knowledge available to engineering education practitioners (only available to engineering education researchers). The pragmatic approach of this research addresses this, a novel aspect and contribution to knowledge.

7. A novel aspect of this research that contributes to knowledge is the value of ICEE within the context of mechanical engineering education. It became evident through the third case study that if learners are encouraged to think outside the immediate topic, in more holistic manner, they appreciate its significance within a wider context. This was another novel aspect of this research which contributes to knowledge.

8.5 Summary

Chapter 9 draws conclusions based on the analysis of the case study results. It identifies the common thread between action learning activities and summarises the findings linked to the original research questions. It summarises the findings linked to the original aims and objectives and the research questions. This chapter also contains the statement of novel content and achievement of the work as a whole - novel aspects and contribution to knowledge.

Chapter 9 – Future work

9.1 Flipped Learning Classroom (FLC) – based on case example 1

In chapter 4 we had proposed future work in the Flipped Classroom approach to teaching and learning. Some of this has already been pursued and the results presented comprehensively at the end of chapter 4 (case study 1) and also summarised within chapter 8 (analysis of case study results).

It is now opportune to reflect back on aspects of Action Research as identified and defined in the literature review (chapter 2) and research methodology (chapter 3).

In accordance to (Kember, 2000), AR should be reflective, systematic and cyclical. I have already reported improvements in assessment results and the learning experience. AR allows us to make further changes in accordance to experience and circumstances. It is subject to the critical and rational judgement. According to (Kemmis and McTaggart, 1988) as part of the continuous cycle this research must plan to improve what has already happened, carry out the plan and observe the subsequent consequences as part of a succession of cycles.

In order to continue with this work in future I seek to identify and introduce new variety in the subject topics whilst also identifying relevant AV and reference websites that can assist in inspirational teaching and learning. I have already identified the complementary link between classroom delivery enhanced by flipped learning and practical (experiential) learning. I must now exploit this further as part of future work by interweaving experiences with classroom delivery. Furthering this research through the AR methodology is of particular importance as AR is still relatively rare in engineering education research (Case and Light, 2011).

As part of future work I also propose to extend the AR beyond the department in which this research was conducted, possibly to another science based discipline, in order to compare outcomes of practice for disparate learners.

9.2 Game Based Learning (GBL) in Mechanical Engineering education – based on case example 2

The GBL activity covered in chapter 5 will be incorporated as part of future delivery of the undergraduate courses and reviewed for improvement on an ongoing basis.

Based on the comments made by several learners a similar activity will be devised in which a mechanical assembly is used as an alternative to the resin puzzle. This would further help introduce principles of mechanical engineering design. Future games will be designed to include aspects such as application of mechanical elements (i.e. bearings, springs and fasteners) and tolerances (limits of fits). These may be incorporated as part of the activity's learning outcomes. This has already been partly fulfilled through the introduction of the reverse engineering of single cylinder air engine assembly (as described in chapter 7). Future work calls for further development of such an activity in order that it becomes more engaging and absorbing for the learner. The current shortcoming of this activity is that it may be criticized for falling short of realising the potential of play, game and story for creating memorable experiences (Hiruni and Stapleton, 2010). To achieve this challenge I need to consider how it is possible to incorporate the nine events interpreted through game design (Becker K. 2006). Variants to this activity along with the introduction of new ones can then be developed. This, it is anticipated, will pose further challenges partly due to existing variances in gaps in prior knowledge amongst learners and issues associated with collaborative learning.

In addition to the investigation of GBL in higher education the researcher is considering extending the study to secondary education environment as part of the STEM initiative. It is proposed to trial this as part of applicant 'taster' days in which young adults are set challenges once they have successfully assembled an education STEM based toy. An example of one such toy is given in figure 9.1 in which theory and play activity are integrated within the same session.

Figure 9.1: The Clementoni 61318 Science Museum-Mechanics Laboratory Toy. An example of an off-the-shelf educational toy which may be used as part of an engaging activity in which theory and play can be integrated within a single session

9.3 ABL and GBL – based on case example 3

The results of this research in GBL/ABL and in particular feedback from students taking part in the research activities has provided a foundation for furthering the approach to other modules on Mechanical Engineering undergraduate courses.

The development of this model can be used as a template in designing future activity work of this nature for other fundamental mechanical engineering disciplines.

We have formed a basis upon which ABL in the Mechanical and Automotive Engineering Design can be extended to include relevant industrial materials and objects (such as fabricated artefacts). It is anticipated that this would lead to better student engagement, attainment, and higher level of knowledge and understanding of engineering design principles.

With exception to the first case study, all the case studies relied on collaborative learning. This was to a lesser or greater extent, depending on the particular case study. With reference to one of the earlier research questions, further investigation is justified:

- Has collaboration enhanced or hindered certain participants and why?

Although collaborative learning is generally beneficial to most learners, it becomes apparent (see review of previous work in collaborative learning in chapter 2) through observations from the case studies that the subject of collaborative learning, as a research area, becomes considerably more complex to address than originally thought. The question as to whether collaborative learning is always beneficial to all learners cannot be answered in a simplistic binary manner. Within collaborative groups, it is probable that learners of opposite ends of the spectrum in ability, knowledge and social skills, are combined. This can lead to inhibition by some learners and frustration for being held back by others. The subject of collaborative learning therefore warrants further research and raises another research question as follows:

- Can learners' results improve based on matching collaborative teams/groups based on ethnicity, cultural and social backgrounds?

Although there has been no scientific process to group learners as part of this research, as part of future work it is proposed that learners are grouped in accordance to their cultural and educational backgrounds. On this basis, the depth of learning may vary, depending on the extent of social interaction and comfort that already exists within groups.

Further research can also identify how to group learners in accordance to personality profiles through psychometric profiling of each group member. By balancing the team accordingly, it may be possible to improve team effectiveness (Belbin, 1993, 2010 and Henry & Stevens, 1999).

9.4 Overall future work

A varied blend of delivery techniques works well. This has been shown in all the case examples. However, the optimum mix and balance of applying such techniques is subject to further work.

An aspect of commonality within almost all of the case studies is collaborative learning. Another aspect is a blend of techniques. As a whole this has been shown that these work well. Further work would seek to identify and understand the learning styles of a small number (minority) of individual learners. For example, certain learners do not thrive in group activities where collaborative learning is required. This therefore is subject to future research. As part of this future work we also wish to address the question as to whether learners' results can improve on the basis of matching collaborative teams/groups based on ethnicity, cultural and social backgrounds.

Emphasis in engineering education should be more on application and integration of knowledge rather than on acquiring wide and deep knowledge. This statement is also supported by (Perrenet et al., 2000). Problem Based Learning, can be further developed in engineering education to bridge gaps between theory and practice in a gradual way. We have partly demonstrated this through Integrated Concurrent Engineering Education (ICEE) but there is much scope for future work encompassing other subjects.

9.5 Summary

In this chapter, the researcher has considered future work that will enable furthering the research. The chapter is based on the highlighted issues and research questions that have arisen as part of the case studies. On the basis that, AR should be reflective, systematic and cyclical I have proposed further work. Some of this work has already been under way and some early results reported.

It has been proposed that flipped learning approach will be put in context and applied to other subject areas within engineering in order to evaluate and quantify its effectiveness and importance in the teaching and learning process.

With reference to case 1 I now feel compelled to incorporate similar delivery for other topics and modules, which may prove effective to a greater or lesser extent and report on this. This has been partly done, post case study 1 and the outcome reported within chapter 4 (case study 1) and summarised in chapter 8 (analysis of case study results).

Future work will also make comparisons in flipped learning techniques such as pre-sessional AV and podcasting.

In this chapter, I have also proposed future work in developing more active learning in Mechanical Engineering, based on what has been drawn from the case studies.

References

Aamodt, A. & Plaza, E. (1994). Case-Based Reasoning: Foundational Issues, Methodological Variations, and Systems Approaches. Artificial Intelligence Communications, 7(1), pp39-59

Abrami, P. C., Poulsen, C. & Chambers, B. (2004). Teacher motivation to implement an educational innovation: Factors differentiating users and non-users of cooperative learning. Educational Psychology, 24 (2), 201–216

Abrami, P., Chambers, B., Poulsen, C., and Kouros, C. (1994). Positive social interdependence and classroom climate. Genetic, Social, and General Psychology Monographs, 120, 327-346

Altrichter H, Kemmis S., McTaggart R., Zuber-Skerritt O., (2002) "The concept of action research", The Learning Organization, Vol. 9 Issue: 3, pp.125-131, Also available online at https://doi.org/10.1108/09696470210428840

Anderson L, Sosniak LA, 1994 Bloom's Taxonomy, a forty-year retrospective ISBN 0-226-60164-1

Anderson L.W. and Krathwohl D.R. (Eds) (2001). A taxonomy for learning, teaching and assessment: A revision of Bloom's Taxonomy of educational objectives: Complete edition, New York: Longman

Anderson L.W., (2002) Curricular Alignment: A Re-Examination, Theory Into Practice, 41:4, 255-260, DOI: 10.1207/s15430421tip4104_9 (https://doi.org/10.1207/s15430421tip4104_9)

Anderson Lorin W. (2002) Theory Into Practice, 41:4, 210-211, DOI: 10.1207/s15430421tip4104_1

Ariffin M.M., Oxley A., Sulaiman S., Evaluating Game-Based Learning Effectiveness in Higher Education, Elsevier, Procedia - Social and Behavioral Sciences 123 (2014) 20 – 27

Aziz, E.-S., Chang, C., Arango, F., Esche, S. K. & Chassapis, C. (2007). Linking computer game engines with remote experiments. Proceedings of the ASME International Mechanical Engineering Congress and Exposition IMECE'07

Baird, J., Andrich, D., Hopfenbeck, T. N., & Stobart, G. (2017). Assessment and learning: Fields apart? Assessment in Education: Principles, Policy and Practice, 24, 317–350.

Barrows HS (1985) How to design a problem based curriculum for the preclinical years. Springer Publishing Co, New York

Barrows, H.S. (1984) A specific problem-based, self-directed learning method designed to teach medical problem-solving skills, and enhance knowledge retention and recall, in: H.G. Schmidt and M.L. De Volder (Eds) Tutorials in Problem-based Learning. A New Direction in Teaching the Health Professions, pp. 16- 32 (Maastricht, Van Gorcum).

Barrows, H.S., A taxonomy of problem-based learning methods. Medical education, 1986, Vol.20, issue 6 pp.481-486

Bates, S. and Galloway, R. (2012). The inverted classroom in a large enrolment introductory physics course: a case study. Proceedings of the HEA STEM Learning and Teaching Conference. DOI:10.11120/stem.hea.2012.071

Bates, S. and Galloway, R. (2012). The inverted classroom in a large enrolment introductory physics course: a case study. Proceedings of the HEA STEM Learning and Teaching Conference. DOI:10.11120/stem.hea.2012.071

Beaty, L. (2003), ‘Supporting learning from experience’ in Fry H., Ketteridge S., Marshall S. (eds), A handbook for teaching and learning in higher education, 2nd Ed. pp.134-147, Kogan Page, London, 2003

Becker K, (2005a). How are Games Educational? Learning Theories Embodied in Games. Paper presented at the DiGRA 2005 2nd International Conference, “Changing Views: Worlds in Play”, Vancouver, B.C., June 16-20,

Becker K, (2010). Video Game Pedagogy: Good Games=Good Pedagogy. In Christopher Thomas Miller (Ed), Games: Purpose and Potential in Education (pp 73-125).Springer, NY 2010 ISBN: 978-1-4419-3533-5

Becker K, (2005b). How are Games Educational? Learning Theories Embodied in Games. Paper presented at the DiGRA 2005 2nd International Conference, “Changing Views: Worlds in Play”, Vancouver, B.C., June 16-20, 2005

Becker k., (2007). Digital game-based learning once removed: Teaching teachers. British Journal of Educational Technology Vol 38 No 3 2007 pp578-488

Becker, K. & Jacobsen, D. M. (2005). Games for learning: are schools ready for what’s to come? DiGRA20052nd International Conference, ‘Changing Views: Worlds in Play’ Vancouver, BC, Canada: Digital Games Research Association.

Belbin M. Management teams — Why they succeed or fail. London: Butterworth Heinemann, 1981.

Belbin, M., (1993). Team Roles at Work. Butterworth-Heinemann, Oxford

Belbin, R.M. (2010), Team Roles at Work, 2nd Edition, Routledge 2010, Abington, Oxon

Bellotti F., R. Berta, A. De Gloria, (2010), Designing effective serious games: opportunities and challenges for research, special issue: creative learning with serious games, Int. J. Emerging Technol. Learn. (IJET) 5 (2010) 22–35.

Biggs, J. (2003). Enriching large class teaching. In Teaching for Quality Learning. 2nd Ed. Open University Press

Biggs. J.B. (2003). Teaching for Quality Learning at University, Society for Research in Higher Education and Open University Press, 2003

Birnbaum, R. (1982). Games & Simulations in higher education. Simulations & Games, 13 (1), 3-11

Bishop JA, Verleger M, ‘The Flipped Classroom: A Survey of the Research’, paper ID 6219, 120th ASEE Annual Conference and Exposition, June 23-26 2013, Atlanta

Black, P., & Wiliam, D. (2018). Classroom assessment and pedagogy. Assessment in Education: Principles, Policy & Practice, 1–25

Blake, J., & Goodman, J. (1999). Computer-based learning: Games as an instructional strategy. The Association of Black Nursing Faculty Journal, 10(2), 43-46

Bligh, D (2002) What's the Use of Lectures? Intellect, Exeter

Bloom, B.S. (1964). Taxonomy of Educational Objectives; the classification of educational goals, by a committee of educational examiners. New York: D. MacKay

Bloom, B.S. (Ed.), Engelhart, M.D., Furst, E.J., Hill, W.H., & Krathwohl, D.R. (1956). Taxonomy of educational objectives: The classification of educational goals. Handbook 1: Cognitive domain. New York: David McKay

Bloom, Benjamin S. (1994). Reflections on the development and use of the taxonomy in Anderson, Lorin W. & Sosniak L.A. (Eds). In Bloom's Taxonomy: A forty-year retrospective. 93rd yearbook of Education, Pt.2. Chicago, IL, University of Chicago Press

Borrego, M. (2007). Conceptual hurdles experienced by engineering faculty becoming engineering education researchers. Journal of Engineering Education 96 (1): 91–102.

Borrego, M., R. A. Streveler, N. Chism, K. A. Smith, and R. Miller. 2006. Developing an engineering education research community of practice through a structured workshop curriculum. In Proceedings, American Society for Engineering Education Annual Conference, Chicago, IL.

Borrego, M., Streveler, A.R., Miller, R.L., Smith, K.A., (2008). A new paradigm for a new Field: Communicating representations of engineering education research. Journal of Engineering Education, April 2008 pp. 147-162

Brown, J. S., & Duguid, P. (1991). Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation. Organization science, 2(1), 40-57

Brown, M, Fry, H and Marshall, S (2003) 'Reflective Practice' in A Handbook for Teaching and Learning in Higher Education. 2nd Ed. Kogan Page ?

Bruner, J S (1966) Towards a Theory of Instruction, Harvard University Press, Cambridge, Massachusetts

Cachay J, Wennemer J, Abele E, Tenberg R (2012) Study on action oriented learning with a Learning Factory approach. Procedia - Social and Behavioral Sciences (55):1144–53

Carr, W., & Kemmis, S. (1986). Becoming critical: Education, knowledge and action research. 1986, Abingdon: Routledge Flamer, Taylor and Francis Group

Carr, W., & Kemmis, S. (2009). Educational action research: A critical approach. In S. Noffke & B. Somekh (Eds.), 2009, Handbook of educational action research (pp. 74–84) London: SAGE

Case, J.M., Light, G., (2011). Emerging methodologies in engineering education research. Journal of Engineering Education. January, 2011, Vol.100, No.1, pp.186-210.

Cashin, W E (1985) Improving Lectures, idea paper 14, Manhattan, Center for Faculty Evaluation and Development, Kansas State University

Chang, C., Arango, F., Esche, S. K. & Chassapis, C., (2007),"On the assembly of experimental setups in virtual laboratory environments", Proceedings of the ASME International Mechanical Engineering Congress and Exposition IMECE'07

Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. Topics in Cognitive Science, 1, 73–105

Chickering A.W., ‘Experience and Learning. An Introduction to Experiential Learning’, Change Magazine Press, 1977, NBW Tower, New Rochelle, New York 10801

Chinnasamy, J. 2013. Mentoring and Adult Learning: Andrology in Action. IJMRR, May 2013, Volume 3, Issue 5, Article No-1, 2835-2844, ISSN: 2249-7196 (https://www.researchgate.net/profile/Jayakumar_Chinnasamy/publication/262764508_MENTORING_AND_ADULT_LEARNING_ANDRAGOGY_IN_ACTION/links/02e7e538c98f153cdb000000/MENTORING-AND-ADULT-LEARNING-ANDRAGOGY-IN-ACTION.pdf) [Accessed 1/2/2019]

Clancey, W. J. (1995). A Tutorial on Situated Learning. In: J. Self (Ed.), Proceedings of the International Conference on Computer and Education (pp. 49-70). Charlottesville, VA: AACE.

www.scopus.com Clifton, Andrew and Mann, Claire, Can you YouTube enhance student nurse learning? Nurse Education Today, 31 (4)(2011).pp311-313 2011 ISSN 0260-6917

Closing the STEM skills gap, report by the Royal Academy of Engineering (https://www.raeng.org.uk/publications/responses/closing-the-stem-skills-gap)

Published January 2017 [Accessed 29/1/2019]

Cohen, E. (1994). Restructuring the classroom: Conditions for productive small groups. Review of Educational Research, 64, 1–35

Cohen, E. G., Brody, C. M., & Sapon-Shevin, M. (2004). Teaching Cooperative Learning. The Challenge for Teacher Education. New York: State University of New York

Comber, B., and H. Nixon. 2011. “Critical Reading Comprehension in an Era of Accountability.” Australian Education Researcher 38: 167–179.

Conrad, D. (2002) Inhibition, integrity and etiquette among online learners: the art of niceness, Distance Education, 23(2), 198–212

Conrad, S. (2010). Effective Digital Game Design for Multi-Generational Learning. (https://files.pbworks.com/download/PenGOGpS0d/immersionfall09/26075333/Digital_Games_For_Learning.pdf) [Accessed 7/12/2014]

Cooley W.W. and Leinhardt G. ,(1980). The Instructional Dimensions Study. Educational Evaluation and Policy Analysis. Jan-Feb. Vol.2, No.1, 1980

Cousin, G. (2009). Researching learning in higher education: An introduction to contemporary methods and approaches. New York, NY: Routledge

Csikszentmihalyi, M. (1990). Flow: The psychology of optimal experience. New York: Harper & Row

Csikszentmihalyi, M. (1996). Creativity: Flow and the psychology of discovery and invention. New York: Harper Collins

Curzon, L. B., & Tummons, J. (2013). Teaching in further education: An outline of principles and practice (7th ed.). London;New York;: Bloomsbury Academic.

Cuseo, J. (2006). Cooperative collaborative structures explicitly designed to promote interdependence among group members (Web page)

http://www.cat.ilstu.edu/additional/tips/coopStruct.php [Accessed 20/12/2018]

Dale, E., Audiovisual Methods in Teaching, Dryden Press, NY, 1969.

Daud, M.F., Taib, J.M., Shariffudin, R.S. (2012). Assessing Mechanical Engineering Undergraduates' Conceptual Knowledge in Three Dimensional Computer Aided Design (3D CAD). International Conference on Teaching and Learning in Higher Education (ICTLHE 2012) in conjunction with RCEE & RHED 2012

David R. Krathwohl (2002) A Revision of Bloom's Taxonomy: An Overview, Theory into Practice, 41:4, pp212-218, DOI: 10.1207/s15430421tip4104_2

De Grove, F., Mechant, P., Van Looy J. (2010), UnCharted waters? exploring experts' opinions on the opportunities and limitations of serious games for foreign language learning, in: Proc.s 3rd Int.l Conf. on Fun and Games, Leuven, Belgium, September, 2010

Deci, E.L., & Ryan, R.M. (1985). Intrinsic motivation and self-determination in human behaviour. New York: Plenum Press

DeFreitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? Computers & Education, Vol 46, 249-269.

Dempsey, J, Lucassen, B., Gilley, W., & Rasmussen, K. (1993-1994). Since Malone's theory of intrinsically motivating instruction: What's the score in the gaming literature? Journal of Educational Technology Systems, 22(2), 173-183

Demsey, J.V., Lucassen, B.A., Haynes, L.L., & Casey, M.S., (1996). Instructional applications of computer games. New York, NY: Annual Meeting of the American Educational applications of computer games. New York, NY:Annual Meeting of the American Educational Research Association. (ERIC Document Reproduction Service No. ED 394 500)

Dewey, J. (1938/1991). Logic: The theory of inquiry. Carbondale: Southern Illinois University Press

Dick, B., (1991), Action Research and Evaluation, Interchange, Brisbane

Donath, L., R. Spray, N. S. Thompson, E. M. Alford, N. Craig, and M. A. Matthews. 2005. Characterizing discourse among undergraduate researchers in an inquiry-based community of practice. Journal of Engineering Education94:403–17

Dorn, D. S. (1989). Simulation Games: One more tool on the Pedagogical Shelf. Teaching Sociology, 17, 1-18.

Downey, G.L., and J.C. Lucena. (2007). Globalization, diversity, leadership, and problem definition in engineering education. In Proceedings of the Inaugural International Conference on Research in Engineering Education. Honolulu, HI.

Driscoll, M. P. (1994). Psychology of learning for instruction. Needham Heights, MA: Paramount Publishing, Inc

Ebenezer, J. V., & Fraser, D. M. (2001). First year chemical engineering students' conceptions of energy in solution processes: Phenomenographic categories for common knowledge construction. Science Education, 85(5), 509–535.

Education Endowment Foundation. (2015). Teaching and learning toolkit. (https://educationendowmentfoundation.org.uk/toolkit/toolkit-a-z/) [Accessed 21/2/2019]

Enactus—Dedicated to making the world a better place through entrepreneurial action (http://enactus.org/) [Accessed 19 May 2018]

Engineering UK 2018: The state of engineering, Synopsis and Recommendations (https://www.engineeringuk.com/media/1576/7444_enguk18_synopsis_standalone_aw.pdf) [Accessed 29/1/2019]

Euchner, J (2014). The Future of Engineering Education. Research Technology Management, 57(1) 15-19

F. Belloti, R. Berta, A. De Gloria, E. Lavagnino, A. Antonaci, F. Dagnino, M. Ott, M. Romero M. Usart, I.S. Mayer (2014). Serious games and the development of an entrepreneurial mind set in higher education engineering students, Entertainment Computing 2014, Elsevier

Fengfeng K. (2008). A case study of computer gaming for math: Engaged learning from gameplay? Computers and Education, 51 (2008) 1609-1620.

Fenner, R.A., Ainger, C.M., Cruickshank, H.J., Guthrie, P.M., (2006). Widening engineering horizons: addressing the complexity of sustainable development. Proc. ICE Eng. Sustain. 4, 145-154.

Formula student competition (https://en.wikipedia.org/wiki/Formula_Student) [Accessed 29/1/2019]

Frame, I. & Hayler, A. (2006). Interactive engagement of students in large class settings using and electronic classroom communication response system. Built Environment Education Conference. Anglia Ruskin University. Higher Education Academy

Franke, J., Hagenah, H., editors. WGP Congress (2013). Advanced Materials Research. Vol. 769; 2013. p. 327 – 334

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8319–8320

Freitas, S., & Oliver, M. (2006). How can exploratory learning with games and simulations within the curriculum be most effectively evaluated? Computers & Education, 2006, Vol 46, 249-269.

Fryer T. (2009). Industry benefits from digital baby boom. Engineering and Technology, Vol. 14, Issue 1, February 2019

Gabriele, G. (2005). Advancing engineering education in a flattened world. Journal of Engineering Education 94 (3): 285–86.

Gagné, R. (1985). The conditions of learning (4th ed). New York: Holt, Rinehart & Winston

Gagné, R.M., Briggs, L.J., & Wagner, W.W. (1992). Principles of instructional design (4th ed.). Fort Worth, Texas: Harcourt Brace Jovanovich College Publishers

Garrison, D. R. & Anderson, T. (2003) E-Learning in the 21st century: a framework for research and practice (London & New York, Routledge Falmer)

Gibbs, G. (1981). Twenty terrible reasons for lecturing. SCED Occasional Paper No 8, Birmingham. Available online at (http://www.brookes.ac.uk/services/ocsld/resources/20reasons.html) [Accessed 18/2/2019]

Gillies, R. (2004). The effects of communication training on teachers' and students' verbal behaviours during cooperative learning. International Journal of Educational Research, 41, 257–279

Gillies, R. M. & Boyle, M. (2005). Teachers' scaffolding behaviours during cooperative learning.

Gillies, R.M., Ashman, A.F. & Terwel, J. (2010), The teacher's role in implementing cooperative learning in the classroom, Springer, New York.

Godwin, P., (2007). The Web 2.0 Challenge to Information Literacy. Presented at INFORUM 2007: Conference on Professional Information Resources, Prague, May 22-24, 2007 (https://www.inforum.cz/pdf/2007/godwin-peter.pdf) [Accessed 6/2/2019]

Graesser A.C., Singer, M., & Trabasso T., (1994), Constructing Inferences during Narrative Text Comprehension. Psychological review, 101, 371-395.

Gunter G.A., Kenny R.F., Vick E.H., (2008). Taking educational games seriously: using the RETAIN model to design endogenous fantasy into standalone educational games. Educational Tech Research Dev (2008) 56:511-537

Gupta S Madhu, (2008). Learning methods of problem solving, IEEE microwave magazine, p134-165, October 2008

Haghighi, K. (2005). Quiet no longer: Birth of a new discipline. Journal of Engineering Education, 94(4), 351–353

Hainey, T., Connolly, T.M. and Boyle, L. (2009). Development and evaluation of a game to teach requirements collection and analysis in software engineering at tertiary education level, In Proceedings of the 3rd European Conference on Games-based Learning (ECGBL), 12-13 October 2009, Graz, Austria.

Hake R. Richard, (1998). Interactive-engagement Vs traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses', American Journal of Physics, 01/1998, Volume 66, Issue 1

Hamari J, Koivisto J and Sarsa H. (2014). Does gamification work? – a literature review of empirical studies on gamification, In IEEE 47th Hawaii International Conference on Systems (HICSS), Waikoloa, HI, USA: IEEE, pp.3025-3034

Hampapur A, Jain R.(1998) Chapter 9: Video data management systems: Metadata and architecture. In: Multimedia Data Management, 1998, McGraw-Hill

Hays, R. T. (2005). The Effectiveness of Instructional Games: A Literature Review and Discussion. Orlando: Technical Report 2005-004 Naval Air Warfare Center Learning Systems Division

Hays, R. T. (2007). Instructional Gaming Handbook: How to select and use instructional game.

Heikkinen H.L.T., Huttunen R., Syrjälä L. Pesonen J. (2012). Action research and narrative inquiry: five principles for validation revisited, Educational Action Research, 2012, 20:1, 5-21, DOI: 10.1080/09650792.2012.647635

Henry S.M. and Stevens K.T (1999). Using Belbin's leadership role to improve team effectiveness: An empirical investigation. The Journal of Systems and Software 44 (1999) 241-250

Higgins, S.E. (2014) 'Formative assessment and feedback to learners.', in Proven programs in education: classroom management and assessment. Thousand Oaks, California: Corwin Press, pp. 11-15.

Hirumi, A. and Stapleton, C., (2010). Applying Pedagogy during Game Development to Enhance Game-Based Learning. In Christopher Thomas Miller (Ed), Games: Purpose and Potential in Education (pp 127-162).Springer, NY 2010 ISBN: 978-1-4419-3533-5

Holly, P (1996), “From action research to collaborative enquiry: the processing of an innovation”, in Zuber-Skerritt, O. (Ed), Action Research for Change and Development, Avebury, Aldershot, pp. 36-56

Holmes, Bryn and Gardner, John, (2008) 'e-learning concepts and practice', Sage pub 2008 ISBN 978-1-4129-1111-5

Hopfenbeck T.N., Classroom assessment, pedagogy and learning twenty years after Black and Wiliam (1998), Assessment in Education: Principles, Policy & Practice, 2018, 25:6, 545-550, DOI: 10.1080/0969594X.2018.1553695 Also available online at (https://doi.org/10.1080/0969594X.2018.1553695)

Horgan J, (2003). ‘Lecturing for learning’ in Fry H., Ketteridge S., Marshall S. (eds), A handbook for teaching and learning in higher education, 2nd Ed. pp.75-90, Kogan Page, London, 2003

Hughes G., (2007) Using blended learning to increase learner support and improve retention. Teaching in Higher Education, 12:3, 349-363

Hughes, G. & Lewis, L. (2003) Who are successful online learners? Exploring the different learner identities produced in virtual learning environments, in: J. Cook & D. McConnell (Eds) Communities of practice. Research Proceedings of the 10th Association for Learning Technology Conference (ALT-C 2003) (UK, The University of Sheffield and Sheffield Hallam University).

Hurst Gregg (2016), The Times, Lead article, ‘New University to Abandon Lecture and charge £12000’ p27, 05-09-2016

J. M. Randel, B. A. Morris, C. D.Wetzel, and B. V. Whitehill, (1992). The Effectiveness of Games for Educational Purposes: A Review of Recent Research, Simulation and Gaming, vol. 23 no.3 (1992): 261–76

Jensen, C.D. (2016). Action research to support development of engineering forsustainable development degree programs, part I: collaborative community action research vignettes. Journal of Cleaner Production 122 (2016) 164-175. Elsevier.

Jesiek, B.K., Newswander, L.K., Borrego, M. (2009). Engineering Education Research: Discipline, Community, or Field? Journal of Engineering Education, January 2009.

Johnson, D. & Johnson, R. (2002). Learning together and alone: Overview and meta-analysis. Asia Pacific Journal of Education, 22, 95–105

Johnson, D. W., & Johnson, R. (1987). Learning together and alone: Cooperative, competitive, and individualistic learning. Englewood Cliffs, NJ: Prentice-Hall

Johnson, D. W., & Johnson, R. (2002). Cooperative learning methods: A meta-analysis. Journal of Research in Education, 12(1), 5–14

Johri, A., & Olds, B. (Eds.) (2014). Cambridge handbook of engineering education research. New York, NY: Cambridge University Press

Jonassen D. (1999). Designing constructivist-learning environments. In C.M. Reigeluth (Ed.), Instructional Design Theories and Models: A New Paradigm of Instructional Theory (pp. 215-239)

Joy, M., (2007). Research methods in education (No.10). The Higher Education Academy, Innovation Way, York Science Park, Heslington, York YO10 5BR

Karau, s., & Williams, k. (1993). Social loafing: a mata-analytic review and theoretical integration. Journal of personality and Social Psychology, 65, 681-706

Kegan, S., and Kegan, M. (1994). The structural approach: six keys to cooperative learning. In S. Sharan (Ed.), Handbook of cooperative learning methods (pp115-133). Westport, CN: Greenwood Press

Keller, J. M., & Kopp, T. W. (1987). Application of the ARCS model to motivational design. In C. M. Reigeluth (Ed.), Instructional theories in action: Lessons illustrating selected theories (pp. 289–320). New York: Lawrence Erlbaum

Kellner, D., Kim, G., (2009). YouTube, Critical Pedagogy, and Media Activism: An Articulation (https://pages.gseis.ucla.edu/.../kellner/.../2009_Kellner-Kim_UT_Politics%20and%20P) [Accessed 6/2/2019]

Kember, D. (2000). Misconceptions about the learning approaches, motivation and study practices of Asian students. Higher Education (2000) 40: 99. https://doi.org/10.1023/A:1004036826490 [Accessed 5/3/2019]

Kemmis, S., Wilkinson, J., Edwards-Groves, C., Hardy, I., Grootenboer, P., & Bristol, L. (2014a). Changing practices, changing education. London: Springer.

Kemmis, S., McTaggart, R., & Nixon, R. (2014b). The action research planner: doing critical participatory action research. Dordrecht: Springer.

Kemmis S. and Taggart, R. (Eds) (1988), The Action Research Planner, 3rd ed., Deakin University Press, Geelong, Victoria.

Kemmis S., (2009) Action research as a practice-based practice, Educational Action Research, 17:3, 463-474, DOI: 10.1080/09650790903093284

Kemmis, S., (2010). What is to be done? The place of action research. Educational Action Research, Vol.18, No.4, December 2010, 417-427.

Kemmis, S., (2006). Participatory action research and the public sphere. Educational Action Research, 14:4, 459-476.

Kemmis, S., and P. Grootenboer. (2008). Situating praxis in practice: Practice architectures and the cultural, social and material conditions for practice. In Enabling practice. Challenges for education, ed. S. Kemmis and T. Smith, 37–64. Rotterdam: Sense.

Kemmis, S., and R. McTaggart. (1986). The action research planner. 3rd ed. Geelong, Vic.: Deakin University Press.

Ketteridge, S and Fry, H (1999) Skills Development in Science and Engineering, Final Project Report to the Department for Education and Employment.

Kim S. (2013). Effects of the gamified class in engineering education environments. Journal of Convergence Information Technology (JCIT) 2013; 8:253-260.

King, A. (1993). Autonomy and question asking: The role of personal control in guided student-generated questioning, invited article of Special Issue of Learning and Individual Differences: Question asking and strategic listening processes: Individual differences and their consequences, 6, 162-185

King, A. (1997). Ask to think-tel why: A model of transactive peer tutoring for scaffolding higher level complex learning. Educational Psychologist, 32, 221–235

King, A., & Rosenshine, B. (1993). Effects of guided cooperative questioning on childrens knowledge construction. Journal of Experimental Education, 61, 127-148

Kingston, N. M., & Nash, B. (2015). Erratum. Educational Measurement: Issues and Practice, 34(1), 55.

Kinsler K. The utility of educational research for emancipatory change. Action Research, 2010, volume 8(2):171-189, Sage publications, Los Angeles, DOI: 10.1177/1476750309351357

Kintsch, W. (1988). The role of knowledge in discourse comprehension: A constructive-integration model. Psychological Reviews, 95, 163-182

Kirriemuir J., Mcfarlane, A. (2004). Literature Review in Games and Learning. A NESTA Futurelab. Research report - report 8. 2004.

Knowles, Malcolm, ‘The modern practice of adult education from pedagogy to andragogy’, Association Press, 1980

Kohno, T., Stubblefield, A., Rubin, A. D., & Wallach, D. S. (2004). Analysis of an electronic voting system. Proceedings of the IEEE Symposium on Security and Privacy, 27-40. Oakland, USA.

Kolb, D. A., (1984) Experiential Learning, Prentice Hall, Englewood Cliffs, New Jersey

Koro-Ljungberg M., Douglas E.P. (2008), State of qualitative research in engineering education: Meta-Analysis of JEE Articles, 2005-2006. Journal of Engineering Education, April 2008.

Krathwohl David R (2002) A Revision of Bloom's Taxonomy: An Overview, Theory in to Practice, 41:4, 212-218, DOI: 10.1207/s15430421tip4104_2

Laurillard, D. (2002) ‘Rethinking university teaching: A conversational framework for the effective use of learning technologies’. Routledge Falmer (http://edutechwiki.unige.ch/en/Laurillard_conversational_framework) [Accessed 18/2/2019]

Lave, J. (1993). Cognition & Technology Group at Vanderbilt. Anchored instruction and situated cognition revisited. Educational Technology, 33(3), 52-70

Lave, J., & Wenger, E. (1990). Situated Learning: Legitimate Peripheral Participation. Cambridge, UK: Cambridge University Press.

Law K.M.Y. (2019). Teaching project management using project-action learning (PAL) games: A case involving engineering management students in Hong Kong. International Journal of Engineering Business Management, 2019 Volume II: 1-7

Law K.M.Y. and Chuah K.B. (2004). Project-based action learning as learning approach in learning organization: the theory and framework. Team Performance Management 2004; 10(9): 178–186

Lepper, M. R., Keavney, M., & Drake, M. (1996). Intrinsic motivation and extrinsic rewards: A commentary on cameron and pierce's meta-analysis. Review of Educational Research, 66(1), 5-32. doi:10.2307/1170723

Levin, M., (2012). Academic integrity in action research. Action Research 10(2) 133-149

Linn, M. C. (2000). Designing the knowledge integration environment. International Journal of Science Education, 22(8), 781–796

Lucena, J., Schneider, J., Leydens, J.A., (2010). Engineering and sustainable community development. Syn. Lect. Eng. Technol. Soc. 5, 1-230

Lucena, J.C., G.L. Downey, B.K. Jesiek, and S. Ruff. (2008). Competencies beyond countries: The re-organization of engineering education in the United States, Europe, and Latin America. Journal of Engineering Education97 (4): 433–47.

Malcolm Knowles, informal adult education, self-direction and andragogy (http://infed.org/mobi/malcolm-knowles-informal-adult-education-self-direction-and-andragogy/) [Accessed 1/2/2019]

Mann, D. (2001). Documenting the effects of instructional technology, a fly-over of policy questions. In W. F. Heineke & L. Blasi (Eds), Research methods for educational technology; methods of evaluating educational technology Vol. 1 (pp. 239–249). Greenwich, CT: Information Age Pub.

Mann, S. J. (2001) Alternative perspectives on student learning: alienation and engagement, Studies in Higher Education, 26(1), 7–19

Mann, S.J. (2005) Alienation in the learning environment: a failure of community? Studies in Higher Education, Vol. 30, No.1, February 2005, pp. 43-55

Markopoulos A.P., Fragkou A., Kasidiaris P.D., and Davim J.P. (2015). Gamification in Engineering education and professional training. International Journal of Mechanical Engineering Education 2015, Vol. 43(2) 118-131

Martin, Helen (2015) Integrating Alternative Teaching & Learning Methods to Enhance the Standard Power Point Lecture. In: Inspire Conference: School of Education and Professional Development, 14 January 2015, University of Huddersfield, UK

Martins, A.A., Mata, T.M., Costa, C.A., (2006). Education for sustainability: challenges and trends. Clean Technol. Environ. Policy 8, 31-37

Mavromihales M., Holmes V., Racasan R. (2018). Game-based learning in mechanical engineering education: Case study of games-based learning application in computer aided design assembly, International Journal of Mechanical Engineering Education 2018, Vol 0(0) 1-24

Mavromihales M., Weston W. (2002). ‘The Application of Rapid Prototyping (RP) Techniques in Higher Education: Training the Engineers of Tomorrow’, paper P2035, Rapid Product Development (RPD) 2002, 8-9 October, CENTIMFE Marinha Grande, Portugal

Mazeyanti M A (2013). GaD-eM: An Adaptive Game Design Model for Malaysian, Proceedings for 3rd Global Conference for Academic Research on Scientific and Emerging Technologies

McFarland R, Reise C, Postawa A, Seliger G. (2013). Learn instruments in value creation and learning centered work place design. In: Seliger G, editor. 11th Global Conference on Sustainable Manufacturing: Innovative Solutions. Universitätsverlag der TU Berlin; 2013. p. 677 – 682

McKeachie, W J (1994) Teaching Tips: Strategies, research and theory for college and university teachers, Heath and Co, Lexington, Massachusetts

McKeachie, W. J. (1990) Teaching and Learning in the College Classroom: A review of the research literature, 2nd edn, MI: NCRIPTAL, University of Michigan, Ann Arbor

McLeod, S. A. (2017). Kolb - learning styles.(www.simplypsychology.org/learning-kolb.html) [Accessed 18/2/2019]

McNiff, J. (2017). Action research: All you need to know. Los Angeles: SAGE

McTaggart, R. (1996), "Action research for aboriginal pedagogy: improving teaching via investigating learning", in Zuber-Skerritt, O. (Ed), Action Research for Change and Development, Avebury, Aldershot, pp. 157-78

Miller, Richard profile (http://www.olin.edu/faculty/profile/richard-miller/) [Accessed 30/1/2019]

Mioduser, D., Betzer, N. (2007). The contribution of Project-based-learning to high-achievers' acquisition of technological knowledge and skills. Int Journal Technology Design Education (2007), 18:59-77

Model of a car created using Garry's Mod: (https://wiki.garrysmod.com/page/Quick_Start)

(http://wiki.garrysmod.com/wiki/?title=Land_Vehicles) [Accessed 23/2/19]

Morka, O.J., Hansena, I.E., Stranda, K., Giskea L.A., Kleppea, P.S., (2016). Manufacturing Education- Facilitating the Collaborative Learning Environment for Industry and University. 6th CLF - 6th CIRP Conference on Learning Factories, 6009 Ålesund, Norway. Procedia CIRP 54 (2016) 59 – 64

Moss, K. and Crowley, M. (2011) Effective Learning in Sciences: The Use of Personal Response Systems with a wide range of audiences. Computers and Education 56, 36 – 43

Nelson L., (1999) Collaborative problem-solving. In: Reigeluth CM (ed) Instructional design theories and models: a new paradigm of instructional theory. Lawrence Erlbaum Associates, Hillsdale, pp 241–267

Nicol, D.J & MacFarlane-Dick (2006). 'Formative assessment and self-regulated learning. A model and seven principles of good feedback practice', Studies in Higher Education. 2006, Vol 31, No 2, pp199-216

Nkhoma MZ, Lam TK, Sriratanaviriyakul N, Richardson J, Kam B, HungLau K (2017) Unpacking the revised Bloom's taxonomy: developing case-based learning activities.

Education + Training 59(3):250–264. (https://doi-org.libaccess.hud.ac.uk/10.1108/ET-03-2016-0061) [Accessed 26 June 2018]

Nystrand, M., Gamoran, A., Kachur, R., & Prendergast, C. (1997). Opening dialogue. New York: Teachers College Press

O'Neil, H. F., Waines, R., & Baker, E. L. (2005). Classification of learning outcomes: Evidence from the computer games literature. The Curriculum Journal, 16(4), 455–474

Olds, B. M., Moskal, B.M., and R. L. Miller (2005). Assessment in engineering education: Evolution, approaches and collaborations. Journal of Engineering Education 94:13–25

Olds, B.M., Borrego, M., Besterfield-Sacre, M., Cox, M. (2012) Guest Editorial: Continuing the Dialog: Possibilities for Community Action Research in Engineering Education. Journal of Engineering Education July 2012, Vol. 101, No. 3, pp. 407–411

Osman, K., Aini B, N. (2012). Educational Computer Games for Malaysian Classrooms: Issues and Challenges. Asian Social Science, 2012, 8(11), 75–84.

Overton, T., (2003), 'Key aspects of teaching and learning in experimental sciences and engineering' in Fry H., Ketteridge S., Marshall S. (eds), A handbook for teaching and learning in higher education, 2nd Ed. pp.255-277, Kogan Page, London, 2003

Passow H.J., (2012). Which ABET Competencies Do Engineering Graduates Find Most Important in their Work? Journal of Engineering Education January 2012, Vol. 101, No. 1, pp. 95–118

Peer, V., Stoeglehner, G., (2012). Universities as change agents for sustainability-framing the role of knowledge transfer and generation in regional development processes. J. Clean. Prod. 44, 85-95.

Perrenet, J.C., Bouhuijs P.A.J. & Smits J. G. M. M. (2000) The Suitability of Problem-based Learning for Engineering Education: Theory and practice, Teaching in Higher Education, 5:3, 345-358

Piaget, J (1950) The Psychology of Intelligence, Routledge and Kegan Paul, London

Potente T, Varandani R, Prote JP. Gamification in management decisions: Judging global production networks in a cyber-physical way. In: Merklein M, Franke J, Hagenah H, editors. WGP Congress 2013. Advanced Materials Research. Vol. 769; 2013. p. 327 – 334.

Prensky M. (2005). "Engage Me or Enrage Me': What Today's Learners Demand," EDUCAUSE Review, vol. 40, no. 5 (September/October 2005): 60–65 (http://www.educause.edu/er/erm05/erm0553.asp) [Accessed 8/2/19]

Prensky M. (2001). Digital Natives, Digital Immigrants Part 1, 2001, On the Horizon, Vol. 9 Iss 5 pp. 1 – 6

Prensky, M. (2003). Digital game-based learning. Computers in Entertainment, 1(1).

Process-Manufacturing-Centre at Kirklees College

(https://www.kirkleescollege.ac.uk/the-college/our-centres/process-manufacturing-centre/) [Accessed 1/3/2019]

Reise C., Muller B., Seliger G. (2014). Resource Efficiency Game – Electric Scooter Game, Proceedings of 21st CIRP Conference on Life Cycle Engineering (2014) 335-360

Radcliffe David F. (Guest Editor). "The Research Agenda for the New Discipline of Engineering Education", 2006, Journal of Engineering Education, vol. 95, no. 4, pp. 259-261.

Ramsden, P (1992) Learning to Teach in Higher Education. Routledge, London

Ramsden, P. (1984). The context of learning. In F. Marton, D. Hounsell, and N. Entwistle, N. (eds), The Experience of Learning. Edinburgh: Scottish Academic Press

Read D. (2010). Happy zapping in the classroom: Enhancing teaching and learning with electronic voting systems. SSR March 2010, 91(996) pp 107-111

Read, B., Archer, L. & Leathwood, C. (2003) Challenging cultures? Student conceptions of ‘belonging’ and ‘isolation’ at a post-1992 university, Studies in Higher Education, 28(3), 261– 277

Reason, P., & Bradbury, H. (Eds.) (2001). Handbook of action research. London: Sage.

Reise Casten, Muller Bastian, Seliger Gunther (2014). Resource Efficiency Game – Electric Scooter Game, Proceedings of 21st CIRP Conference on Life Cycle Engineering (2014) 335-360

Riley, D., (2011). Engineering thermodynamics and 21st century energy problems: a textbook companion for student engagement. Synthesis Lect. Eng. 3, 1-97

Rivera JC, McAlister MK. (2001). A comparison of student outcomes & satisfaction between traditional & Web based course offerings. Proceedings of 2001 Information Resources Management Association International Conference, May 20–23, 2001, Ontario, Canada

Romero, M. Usart, M. Ott, J. Earp, S. de Freitas, S. Arnab, (2012). Learning through playing for or against each other? Promoting Collaborative Learning in Digital Games Based Learning. Proceedings of the ECIS conference, Barcelona June 2012

Ross, J.A., & Cousins, J.B. (1994). Intentions to seek and give help and behaviour in cooperative learning groups. Alberta Journal of Educational Research, 89, 109-117

Rossiter, J. A. (2014). Experiences of and resources to enable lecture flipping in systems and control engineering. Higher Education Academy STEM

Rossiter, J.A. and Rossiter, D. (2014). ‘Student usage of web-based resources for engineering teaching’, in Proc. UKACC (2004)

Rossiter, J.A. Which technology can really enhance learning within engineering? International Journal of Electrical Engineering Education, 2011, 48/3

Russell, M., (2008). Using an electronic voting system to enhance learning and teaching. Engineering Education: Journal of the Higher Education Academy Engineering Subject Centre, 3(2) (2008), 58–65

Salmon G, Jones S and Armellinia A. (2008). Building institutional capability in e-learning design. ALT-J, Research in Learning Technlogy, Vol.16, No.2 June 2008, 95-109

Salmon G. (2003). E-moderating: The key to teaching and learning online. 2003, 2nd edition London: Routledge Falmer

Salmon Gilly, Nie Ming & Edirisingha Palitha (2010) Developing a five-stage model of learning in Second Life , Educational Research, 52:2, 169-182, DOI:10.1080/00131881.2010.482744

Schank RC, Berman T.R., Macpherson KA (1999) Learning by doing. In: Reigeluth C.M. (ed) Instructional design theories and models: a new paradigm of instructional theory. Lawrence Erlbaum Associates, Hillsdale, pp 161–179

Seaborn K. and Fels D.I. (2015). Gamification in theory and action: a survey. International Journal Human Computer Studies 2015; 74: 14–31

Shavelson, R., and Towne, L. (2002). Scientific Research in Education, Washington, D.C.: National Academies Press, 2002. Scientific Research in Education, Washington, D.C.: National Academies Press, 2002.

Sherwin K., Mavromihales M.,'Design of a heat exchanger' (1999). International journal of Mechanical Engineering Education, pp209-216 Vol.27 No.3 July 1999.

Sherwin K., Mavromihales M. (1999). 'Design, Build and Testing of a Heat Exchanger as a student project', Conference of American Society of Engineering Education, Charlotte, NC, USA,20-23 June 1999.

Simpson, O. (2003) Student retention in online, open and distance learning (London, Kogan Page)

Simpson, O. (2004) The impact on retention of interventions to support distance learning students, Open Learning, 19(1), 79-95

Skiba, D.J., (2007), Nursing Education 2.0: YouTube. Nursing Education Perspectives 28(2), 100-102

Slevin J. (2008), E-learning and the transformation of social interaction in higher education, Learning, Media and Technology, (2008) 33:2, 115-126

Sotomayor, T. M., & Proctor, M.D. (2009). Assessing Combat Medic Knowledge and Transfer Effects Resulting from Alternative Training Treatments. The Journal of Defence Modelling and Simulation: Applications, Methodology, Technology, 6(3), 121-134.

Stapleton, C.B., & and Hughes, C.E. (2006). Believing is seeing: Cultivating radical media innovations. Computer Graphics and Applications. 26(1), 88-93

Streveler R.A., Mekekse M., (2017). Guest Editorial: Taking a closer look at active learning. Journal of Engineering Education, April 2017, Vol. 106, No.2, pp. 186-190

Streveler, R. A., & Smith, K. A. (2006). Guest Editorial: Conducting rigorous research in engineering education. Journal of Engineering Education, 95, 103–105

Sujo de Montes, L., Oran, S. & Willis, E. (2002) Power, language and identity: voices from an online course, Computers and Composition, 19, 251–271

Swanson, Richard A. (2013). Theory Building in Applied Disciplines. San Francisco, CA: Berrett-Koehler Publishers 2013

Syed M.R. (2001). Diminishing the distance in distance education. IEEE Multimedia July–Sept., 2001:18–21

Taber, K. S. (2000). Case studies and generalizability: Grounded theory and research in science education. International Journal of Science Education, 22(5), 469–487.

Tait, J. (2004) The tutor/facilitator role in student retention, Open Learning, 19(1), 97-109

The Harvard University, Program on Survey Research Tip Sheet on Question Wording URL: (http://psr.iq.harvard.edu/book/questionnaire-design-tip-sheet) [Accessed 12/12/2015]

Thomas T.R. (2010), Lessons of Mastery Learning. Interventions that work. October 2010, Volume 68, Number 2 Page 52-57

Timmis, S, Broadfoot, P, Sutherland, R & Oldfield, A. (2016), 'Rethinking assessment in a digital age: opportunities, challenges and risks'. British Educational Research Journal, vol. 42, pp. 454 -476

UK engineering facing skills crisis: where are the jobs? (https://www.randstad.co.uk/job-seeker/career-hub/archives/uk-engineering-facing-a-skills-crisis_1101/) [Accessed 29/1/2019]

UK government website comparing various qualifications URL: (https://www.gov.uk/what-different-qualification-levels-mean/overview) Last updated October 1 2015. [Accessed 12/12/2015]

UK Standard for Professional Engineering Competence (UK-SPEC), Engineering Council, London, 2013

UK-SPEC online, The Engineering Council, (http://www.engc.org.uk/engcdocuments/internet/Website/UK-SPEC%20third%20edition%20%281%29.pdf) [Accessed 1/11/2015]

University of Southern California, Research Guides, last revised November 3 2015. URL: (http://libguides.usc.edu/writingguide) and (http://libguides.usc.edu/content.php?pid=83009&sid=618409) [Accessed 21/11/2015]

Unver E., Mavromihales M., (2001). 'Design and Development of an Interactive 3D CNC Computer Aided Learning (CAL) Program'. pp348-356, Volume 1, Proceedings of 17th International Conference on CAD/CAM, Robotics and Factories of the Future, CARS & FOF 2001, Durban, South Africa.

Van Eck, R. (2006). Digital game-based learning: it's not just the digital natives who are restless, EDUCAUSE Rev. 41 (2)

Van Hanh N., Hop N.H. (2018), The effectiveness of the industrial field trip in introduction to engineering: A case study at Hung Yen University of Technology and Education, Vietnam. International Journal of Electrical Engineering Education, Vol. 55(3) 273-289, 2018

Van Sickle R.L. (1986), A Quantitative Review of Research on Instructional Simulation Gaming: A Twenty-Year Perspective, Theory and Research in Social Education, vol. 14, no. 3 (1986): 245–64

Veenman, S., Denesen, E., van den Akker, A., & Van der Rijt, F. (2005). Effects of a cooperative learning program on the elaborations of students during help seeking and help giving. American Educational Research Journal, 42, 115-152

Vygotsky, L. (1978). Mind in Society: Development of Higher Psychological

Vygotsky, L.S., & Cole, M. (1977). Mind in society: the development of higher psychological processes. Cambridge Harvard University Press

Vygotsky, L.S.; Hanfmann, Eugenia; Vakar, Gertruda; Kozulin, Alex, (2012), 'Thought and Language' Rev and expanded ed, MIT Press 2012, Cambridge 2012

Vygotsky' framework (http://jan.ucc.nau.edu/lsn/educator/edtech/learningtheorieswebsite/vygotsky.htm) [Accessed 8/11/2016]

Webb, N. & Mastergeorge, A. (2003). Promoting effective helping in peer-directed groups. International Journal of Educational Research, 39, 73–97

Webb, N. M., & Palincsar, A.S. (1996). Group processes in the classroom. In D.C. Berliner and R.C. Calfee (Eds.), Handbook of educational psychology (pp. 841-873). New York: Macmillan

Webb, N.M. (1989). Peer interaction and learning in small groups. International Journal of Educational Research, 13, 21-40

Wellington, J. J. (2000). Educational research: Contemporary issues and practical approaches. London: Continuum.

Weston T.J., Barker L. (2001). Designing, implementing, and evaluating Web based Learning modules for university students. Educational Technology 2001; 41(4):15–22

Wiliam, D. (2018). Assessment for learning: Meeting the challenge of implementation. Assessment in Education: Principles, Policy & Practice. 2018, 25(6), 686–689.

Wiliam, Dylan (2017). Assessment and learning: some reflections, Assessment in Education: Principles, Policy & Practice, 24:3, 394-403, DOI:10.1080/0969594X.2017.1318108

Wiliam, Dylan (2018). Assessment for learning: meeting the challenge of implementation, Assessment in Education: Principles, Policy & Practice, 25:6, 682-685, DOI: 10.1080/0969594X.2017.1401526

William F, Bareiss R, Birnbaum L, Osgood R. (1992). ASK systems: An approach to the realization of story-based teachers. Technical Report, No. 22, Institute for the Learning Sciences, 1992

Zhang D. (2003), Powering E-learning in the new millennium: An overview of e-learning and enabling technology. Information Systems Frontiers 2003, 5:2, 201-212

Ziming, Q. (2008) Industry oriented teaching and learning strategies applied to the course within traditional engineering technology undergraduate program. 38th ASEE/IEEE Frontiers in Education Conference, F2E-1, October 22 – 25, 2008, Saratoga Springs, NY

Zmeyov Serguey I. (1998), Andragogy: Origins, Developments and Trends, International Review of Education, Vol. 44, No1 (1998), pp 103-108 (https://nmite.org.uk/new-university-to-abandon-lectures-and-charge-12000/) [Accessed 30/1/2019]

Zuber-Skerritt, O. (2001), “Action learning and action research: paradigm, praxis and programs”, in Sankaran, S., Dick, B., Passfield, R and Swepson, P. (Eds), Effective Change Management Using Action Research and Action Learning: Concepts, Frameworks, Processes and Applications, Southern Cross University Press, Lismore, Australia, pp. 1-20

http://users.ipfw.edu/sternber/339/framework.html On Theoretical Frameworks [Accessed 9/10/2014]

A summary of Vgotsky’s emphasis on the social dimension of learning URL: http://jan.ucc.nau.edu/lsn/educator/edtech/learningtheorieswebsite/vygotsky.htm [Accessed 4/11/2015]

Appendix

This appendix contains the questionnaires used to evaluate participants’ feedback for the case studies, as part of this research.

Questionnaire used in case study 1 – Flipped Classroom

Following delivery of the session, please answer the following questions:

1. You were asked to watch three AV clips on YouTube prior to the schedule class. Three clips were given of duration 7.5 mins, 24 mins and 1.6 mins

Which of the following best fits what you did? Tick all that apply

❒ Yes I watched all three fully

❒ No I didn't watch any of them

❒ I only watched some of them, partly or fully

❒ I only watch the short ones (7.5 & 1.6 mins)

❒ I watched part of the longest one

2. If you didn't watch all three clips, what was your reason?

❒ No interest

❒ They were too long and I didn't have time or didn't want to dedicate the time outside lecture time

❒ I didn't think I needed to watch all three as watching was recommended and not essential

❒ Other (Please state)…………………………………………………………………………………………

3. If you watched any, did you think it was worthwhile watching the recommended viewings prior to class?

❒ Yes

❒ No

❒ Not applicable as I didn't watch

❒ Not sure

4. Do you think you benefitted more during the timetabled lecture session by viewing the AV material, more than if you hadn't?

❒ Yes

❒ No

❒ Not applicable as I didn't watch

❒ Don't know

5. Do you think more classroom sessions should be organised and delivered like this?

❒ Yes

❒ No

❒ Don't know

6. How do you rate delivery of the session in comparison to usual sessions?

❒ Better than usual sessions in that it was more interactive

❒ I found it more informative and interesting than usual sessions, partly due to prior viewing

❒ It was no different to usual sessions

❒ Not sure/indifferent

7. I liked the subject matter, in that I found it interesting and relevant to the module and course

❒ True

❒ False

❒ Indifferent

8. Did you participate in the discussion in any way?

❒ Yes, by asking the tutor a question, or a peer/fellow student

❒ No, I just listened

❒ No, I lost interest

9. Would you like more sessions in this module (lectures only) to be conducted in the same way (by prior viewing or demonstrations)?

❒ Yes

❒ No

❒ Some but not all

Add your comment here (optional)………………………… …………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………

10. If you answered No in the last question, what is your reason?

❒ Disliked having to prepare before class

❒ Would rather be given all the information during class, including AV demonstrations

❒ Other, please specify
………………………………………………………………………………………

Add your own comments here if you wish

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
……………………………………………………………………………

TERM 1 ASSEMBLY GAME FEEDBACK QUESTIONNAIRE (16/17 ACADEMIC YEAR)

Please answer by indicating whether you agree or disagree with the following statements.

1. I applied skills and knowledge gained in the 2 weeks prior to the game. These were further underpinned during the game

Do you think the event achieved this?

❒ Agree

❒ Disagree

❒ Comment (optional)
…………………………………………………………………………………………

2. The game was fun whilst it also introduced an element of competition against my peers within an Activity Based Learning environment

❒ Agree

❒ Disagree

❒ Comment (optional)
…………………………………………………………………………………………

3. I collaborated effectively with a peer to solve the puzzle quiz which required mechanical assembly aptitude (physical), virtual assembly skills (Computer Based Assembly) and verbal communication - Problem solving by applying logic, skill and communication.

❒ Agree

❒ Disagree

❒ Comment (optional)
…………………………………………………………………………………………

4. It provided a means of formative self-assessment – To gauge my own standard and against that of my peers

❒ Agree

❒ Disagree

❒ Comment (optional)
………………………………………………………………………………………

5. The activity was a refreshing change from a ‘traditional’ practical session in which an exercise was given to practice with instruction (only guidelines were provided for the game)

❒ Agree

❒ Disagree

❒ Comment (optional)
………………………………………………………………………………………

6. My visual memory from the physical mechanical assembly helped me in the virtual assembly using Solidworks?

❒ Agree

❒ Disagree

❒ Partly

❒ Comment why you answered in this way…………………………………………………………………

7. Working with another person helped me in completing the exercise effectively? Was it helpful working with a peer?

❒ Yes

❒ No

❒ Partly

❒ Comment why you answered in this way…………………………………………………………………

8. Do you think more classroom sessions should be organised like this? (Activity based learning)

❒ Yes

❒ No

❒ Comment (optional)
……………………………………………………………………………………………

9. Do you think that the activity has helped you develop your skills in Solidworks further?

❒ Yes

❒ No

❒ Comment (optional)
……………………………………………………………………………………………

10. I found the activities interesting and relevant to the module and course.

❒ Yes I agree

❒ No I disagree

❒ I neither agree nor disagree

❒ Comment why you answered in this way……………………………………………

Any other comments you would like to add?

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

Student number (optional but preferred) ………………………………………………

TERM 2 ACTIVITY GAME FOR NIM2211 (MECHANICAL DESIGN) QUIZ CARDS FEEDBACK QUESTIONNAIRE (17/18 ACADEMIC YEAR)

Please answer by indicating whether you agree or disagree with the following statements.

1. I applied skills and knowledge previously gained on my course and these were further underpinned during the game (i.e. surface finish, tolerances, processes for manufacture)

Do you think the event achieved this?

❒ Agree

❒ Disagree

❒ Comment (optional)
…………………………………………………………………………………………

2. The game was fun whilst it also introduced an element of competition against my peers within an Activity Based Learning environment

❒ Agree

❒ Disagree

❒ Comment (optional)
…………………………………………………………………………………………

3. I collaborated effectively with peers to address the quiz card questions. This required information finding skills and verbal communication - Problem solving by applying reason, knowledge, skill and communication.

❒ Agree

❒ Disagree

❒ Comment (optional)
…………………………………………………………………………………………

4. It provided a means of formative self-assessment – To gauge my own knowledge against that of my peers

❒ Agree

❒ Disagree

❒ Comment (optional)
…………………………………………………………………………………………

5. The activity was a refreshing and welcome activity during studio sessions

❒ Agree

❒ Disagree

❒ Comment (optional)

…………………………………………………………………………………………………

6. I was clear of what was required in order to participate in the activity and the general rules were clear.

❒ Agree

❒ Disagree

❒ Partly

❒ Comment why you answered in this way……………………………………………

7. Working with another person helped me in completing the exercise effectively? Was it helpful working with a peer?

❒ Yes

❒ No

❒ Partly

❒ Comment why you answered in this way……………………………………………….

8. Do you think more studio sessions should be organised like this? (Activity based learning)

❒ Yes

❒ No

❒ Comment (optional) ………………………………………………………………

9. I found the activity interesting and relevant to the module and course (detail design, including, materials, surface finish, tolerances and how things are made)

❒ Yes I agree

❒ No I disagree

❒ I neither agree nor disagree

❒ Comment why you answered in this way……………………………………………

Any other comments you would like to add?

…………………………………………………………………………………………….
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Student number (optional but preferred) ………………………………………………

TERM 2 AIR ENGINE ASSEMBLY AND DETAILING ACTIVITY FEEDBACK QUESTIONNAIRE (18/19 ACADEMIC YEAR)

You have been provided with the 3D Solidworks parts for a miniature air engine and asked to complete an assembly within Solidworks. You were then asked to work in pairs to detail each part for production by considering, dimensions, tolerances and surface finish. This questionnaire aims to establish whether you feel that you have gained from this activity.

Please answer by indicating whether you agree or disagree with the following statements.

1. I have previously covered tolerances and/or surface finish definition whilst either on this course or at another institution.

❒ Agree

❒ Disagree

❒ Unsure

❒ Comment (optional) …………………………………………………………………

2. The exercise helped reinforce previously gained knowledge and/or provided me with new knowledge on tolerances and surface finish.

❒ Agree

❒ Disagree

❒ Comment (optional) ……………………………………………………………………

3. I now feel more confident that I can complete drawings for production whilst also defining dimensional tolerances and surface finish.

❒ Agree

❒ Disagree

❒ Comment (optional) ……………………………………………………………………

4. I collaborated effectively with a peer to dimension the components by checking each other's work and making corrections accordingly.

❒ Agree

❒ Disagree

❒ Comment (optional) ……………………………………………………………………

5. It was helpful to me when the tutor had gone through the recommended method for dimensioning and applying tolerances as it provided me with feedback on my work.

❒ Agree

❒ Disagree

❒ Comment (optional) …………………………………………………………………………

6. Overall, the activity was enjoyable and I would welcome more activities like it which use physical artefacts as a focus for the session.

❒ Agree

❒ Disagree

❒ Comment (optional) …………………………………………………………………………

7. My dimensioning skills using Solidworks have improved during the current academic year due to the practical work covered as part of this module in CAD/CAM.

❒ Agree

❒ Disagree

❒ Comment (optional) …………………………………………………………………………

8. I now feel more confident that I can apply tolerances using Solidworks to stipulate a type of fit (clearance or transitional)

❒ Agree

❒ Disagree

❒ Comment (optional) …………………………………………………………………………

9. I think that there is sufficient content on this module for Solidworks assembly and drawing/detailing.

❒ Agree

❒ I disagree, I would like more assembly and drawing

❒ I disagree, I would like less assembly and drawing

❒ Comment why you answered in this way……………………………………………

10. Working with another person helped me in completing the exercise effectively. Was it helpful working with a peer?

❐ Yes

❐ No

❐ Partly

❐ Comment why you answered in this way……………………………………………

11. Do you think that the activity has helped you develop your skills in Solidworks further?

❐ Yes

❐ No

❐ Comment (optional) ………………………………………………………………

Any other comments you would like to add?

…………………………………………………………………………………………….

……………………………………………………………………………………………

……………………………………………………………………………………………

Student number (optional but preferred)…………………………………………………