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MA in Teaching & Learning

Module: Dissertation (EDU7050)

“The Utilisation of Project - Based and Problem - Based Learning for the transition towards Active Learning and Critical Thinking for Undergraduate Motorsport learners”

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List of Abbreviations

**ARP**: Action Research Project

**ABET**: Accreditation Board for Engineering and Technology

**BEng**: Bachelor of Engineering

**BSc**: Bachelor of Science

**BTEC**: Business and Technology Education Council

**CAS**: Computer Algebra System

**CDIO**: Conceiving — Designing — Implementing — Operating

**CEng**: Chartered Engineer

**ECUK**: Engineering Council UK

**FS**: Formula Student

**HE**: Higher Education

**H₀**: null hypothesis

**H₁**: alternative hypothesis

**ICT**: Information & Communications Technology

**IEng**: Incorporated Engineer

**IET**: Institution of Engineering and Technology

**IMechE**: Institution of Mechanical Engineers

**MEQs**: Module Evaluation Questionnaires

**MSP5001**: ‘Chassis Development and Telemetry’ module

**MSP4006**: ‘Performance Engineering Sciences’ module

**MSP4001**: ‘Chassis and Electronic Principles’ module

**MSP4007**: ‘Engineering Mathematics’ module

**MSP4005**: ‘Applied Analytical Methods’ module

**NCME**: National Centre for Motorsport Engineering

**PBL**: Problem – Based Learning

**PJL**: Project – Based Learning

**r**: Pearson Product-moment Correlation Coefficient
R&D: Research and Development
RQ: Research Question
UK-SPEC: UK Standard for Professional Engineering Competence
2-D: two-dimensional
3-D: three-dimensional
Abstract

This work focuses on Project and Problem-based Learning as assistive educational tools for the transition of HE undergraduate motorsport engineering learners towards active and critical thinking. An Action Research Project (ARP) was developed focusing on the ‘Chassis Development and Telemetry’ module which is delivered during the second year of the undergraduate motorsport courses at the National Centre for Motorsport Engineering of the University of Bolton. This module has a strong hands-on element and therefore, it is appropriate for learners that begin to develop active learning and critical thinking skills as well as other employability (transferable) skills. The ARP included a series of hands-on portfolio exercises in the area of analysis and processing of signals acquired from racecar sensors and incorporated features aiming to simulate the professional motorsport environment within the HE framework. The quantitative analysis included, apart from basic statistical analysis, the use of the Pearson Product-moment Correlation Coefficient, the k-means algorithm and the Wilcoxon rank sum test. The observations and conclusions stemming from the analysis of the ARP regarding the incorporation of project and problem-based learning were very encouraging; they indicated that the learners’ satisfaction levels improved through the delivery of a series of exercises which involved analysis and processing of authentic signals acquired from racecar sensors. Moreover, the quantitative analysis indicated a positive correlation between the learners’ prior knowledge and their academic performance in the ARP, for one of the two groups of students.
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Moreover, I would like to especially thank my supervisor Dr. Daniela Bacova for her continuous guidance and support, her role as ‘critical-friend’ and for helping me set the framework of my research.

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CHAPTER 1: Introduction

1.1 The NCME Courses

The National Centre for Motorsport Engineering (NCME) – previously named Centre for Advanced Performance Engineering (CAPE) – was founded in 2013 and is part of the School of Engineering of the University of Bolton, UK. NCME delivers two motorsport-oriented courses, a Bachelor of Engineering (BEng) in Automotive Performance Engineering and a Bachelor of Science (BSc) in Motorsport Technology. The BEng course is more appropriate for students with a more traditional academic background such as A-Levels or International Baccalaureate (IB) who have studied Mathematics, Science and Science-related modules, whereas the BSc course is aimed at learners from a vocationally oriented background, such as Business and Technology Education Council (BTEC) qualification holders who have successfully completed Mathematics’ and Science-related modules as part of their qualifications.

1.2 An Action Research Project (ARP) for the ‘Chassis Development and Telemetry’ module (Racecar Data Acquisition)

This work is based on an Action Research Project (ARP) which was developed in relation to the second-year ‘Chassis Development and Telemetry’ module and will be presented in depth in the following chapters. The ‘Chassis Development and Telemetry’ is a module common to both BEng and BSc NCME courses and provides the learners with knowledge and employability skills necessary for the profession of Motorsport Data engineer. In essence, a Motorsport Data Engineer extracts data (signals) through a network of sensors which have been installed in certain places around a vehicle, processes and analyses the signals aiming to make informed decisions in relation to the set-up of the racing car as well as to provide drivers with guidance and directions on how to improve their driving performance.

The learners are expected to develop knowledge and skills, to the appropriate level, that will enable them monitor and analyse a racing car’s or a driver’s performance. Hence, they need to have gained knowledge of basic mathematical / analytical
concepts, science principles and basic programming knowledge in Year 1. This particular area of knowledge is covered through the ‘Applied Analytical Methods’ and ‘Chassis and Electronic Principles’ modules for the BSc students and ‘Engineering Mathematics’ and ‘Performance Engineering Sciences’ modules for the BEng students. Concepts introduced in the aforementioned modules subsequently find application in the practical exercises which form the portfolio for the second-year module ‘Chassis Development and Telemetry’.

1.3 The Role of Software in Engineering Teaching & Learning

To acquire data from sensors located on racing cars and transfer them to a PC / laptop, specialised commercial software (e.g. MoTeC) is utilised (MoTeC, 2017). However, for more challenging and demanding analysis and signal processing related to advanced and more complex applications, mathematical-oriented software such as Microsoft Excel (Microsoft, 2017) or MATLAB (Mathworks, 2017) should be utilised instead.

MATLAB is an educational and research mathematical programming software utilised by the majority of Higher Education (HE) Engineering and Science Schools worldwide as well as by most Research and Development (R&D) departments in industry. In Higher Education, MATLAB is used primarily as a tool for: i) teaching and learning mathematics and science, ii) introducing the learners to programming, iii) data visualisation applications and iv) signal analysis, processing and simulation (Mathworks, 2017). The data visualisation, signal processing and simulation capabilities of MATLAB are usually utilised during the second and third year of an engineering undergraduate course, whereas the teaching and learning capabilities are introduced during the first year.

1.4 Professional Accreditation Bodies: Requirements & Objectives

Due to their multidisciplinary nature, Motorsport Engineering courses in Higher Education can be accredited by either the Institution of Mechanical Engineers (IMechE) or the Institution of Engineering and Technology (IET). Note that the IMechE professional body specialises on the accreditation of HE Mechanical Engineering-related courses and the IET professional body on the accreditation of
HE Electrical and Electronic Engineering-related courses (Institution of Mechanical Engineers, 2018; The Institution of Engineering and Technology, 2018). Both NCME courses lie in the area of mechanical engineering and therefore, the content delivered is mainly influenced by the Institution of Mechanical Engineers (IMechE) which is a licensed member of the Engineering Council (Engineering Council, 2017a).

In 2016, both courses were accredited via the IMechE, meaning that BEng and BSc graduates are able to follow a career path towards Chartered Engineer (CEng) and Incorporated Engineer (IEng) professional registration, respectively (Engineering Council, 2017c); however, the CEng registration requires additional competencies and skills compared to the IEng registration. Full-time students are expected to complete six modules per academic year, four of which are common to BEng and BSc students; common modules’ Learning Outcomes are aligned to the CEng status requirements.

The IMechE accreditation requirements are expressed through the ‘Competence and Commitment Standards for Chartered and Incorporated Engineers’; in relation to the ‘Chassis Development and Telemetry (MSP5001)’ module, these requirements are fulfilled via the learning and teaching strategy as well as the ‘Formative and Summative Assessment Strategy’. Since the MSP5001 module is common to the BEng and the BSc course, the Standards for both the Incorporated as well as the Chartered Engineers should be fulfilled.

As described in the UK Standard for Professional Engineering Competence, published by the Engineering Council (Engineering Council, 2017b), a Chartered Engineer should be able to: “Conduct appropriate research, and undertake design and development of engineering solutions” for example to: “Collect, analyse and evaluate the relevant data. Carry out formal theoretical research. Evaluate numerical and analytical tools. Carry out applied research on the job.” Engineering students, therefore, should develop the required knowledge in order, for example, to process and analyse sensor signals using educational computer software (e.g. MATLAB) and also have the ability to understand and replicate the analysis made by commercial software.
1.5 Key Objectives of the Dissertation / Research Aim:

Based on the Action Research Project (ARP) developed for the year-2 ‘Chassis Development and Telemetry’ module, there will be an investigation on the role that Project-based and Problem-based Learning (PJL and PBL, respectively) can play in facilitating the process of transforming students from ‘passive’ learners during Year 1 to independent and critical thinkers in Year 2 through Active Learning; in other words, the students’ ability to utilise, relate and combine concepts, methods and tools obtained during the first year for developing applied knowledge in an engineering framework involving motorsport applications, always in agreement with the Engineering Council’s standards and requirements, will be explored.

Furthermore, the role of mathematical-related software as a tool for teaching and learning, as well as a potential tool for the transition from passive to independent and critical thinking will be discussed. This study will also explore the potential relationships between the students’ academic performance in Year-1 Mathematics, Science and Computer programming / software modules and the ‘Chassis Development and Telemetry’ module as well as the ARP’s efficiency compared to other modules delivered by the School of Engineering and the University.

This dissertation will investigate the learning journey of the students towards critical thinking, focusing on: (1) the role of the analytical / mathematical, scientific and engineering principles delivered via the Year 1 modules, (2) the utilisation of these principles for a Year 2 module with strong hands-on elements, (3) the importance of Problem-based and Project-Based Learning and (4) the role of software as a facilitator for the aforementioned transition process.

Two different Research Questions will be investigated in relation to the ‘Chassis Development and Telemetry (MSP5001)’ module. The first Research Question (RQ 1) explores whether there is a correlation between the learners’ prior knowledge and their performance in the portfolio exercises introduced in the ARP of the MSP5001 module. Specifically, it explores whether a relationship exists between the learners’ marks in the Mathematics and Science-related Year 1 modules and their marks in the Year 2 MSP5001 ARP.

The second Research Question (RQ 2) investigates whether the intervention (MSP5001 ARP) introduced by the tutor will further connect the theoretical with the practical aspects of the MSP5001 module. In other words, it is explored whether the
delivery of the MSP5001 module improved the students’ learning experience in certain areas such as module content and relevancy of assessment methods compared with the delivery outcomes of the other modules at the (i) School of Engineering and (ii) University.

Note that in this work the terms tutor and author are used interchangeably.

1.6 Roadmap to the Dissertation

This dissertation is organised as follows: In chapter 2, a Literature Review in relation to Motorsport Education, Project-Based, Problem-Based, Active Learning and the role of software in the Engineering Education curriculum is provided. Chapter 3, which is the Methodology chapter, outlines the quantitative methods selected in order to analyse and convert data into information, namely, the Scatterplot and the Pearson Product-moment Coefficient, the k-means algorithm and the Wilcoxon rank sum test. In chapter 4, the methods described in chapter 3 are put into practice for processing and analysing the data (learners’ module results during Year 1 and Year 2, formal feedback retrieved from Module Evaluation Questionnaires - MEQs - for the ‘Chassis Development and Telemetry’ module as well as informal feedback from students during academic Year 2). In chapter 5, the results are related to the corresponding theory in the literature review, certain patterns are identified, and observations are made in relation to the delivery of the ‘Chassis Development and Telemetry (MSP5001)’ module. Chapter 6 presents an overall summary and conclusions of this work alongside research limitations and weaknesses as well as recommendations for future research.
2.1 Introduction

As mentioned in chapter 1, this work focuses on an Action Research Project (ARP) which has been developed in relation to the ‘Chassis Development and Telemetry’ module, a module common to second year BEng and BSc Motorsport courses at the University of Bolton, which mainly involves the utilisation of information extracted from sensors installed in racing cars. The ‘Chassis Development and Telemetry’ module may be considered as rather challenging in its delivery, as learners have diverse backgrounds, either academically or vocationally oriented, and also it is a hands-on, application-oriented module where the learners are expected to develop their own knowledge through project-based and problem-based learning.

In this work, the Action Research Project (ARP), developed for the ‘Chassis Development and Telemetry (MSP5001)’ module, aimed to introduce a more hands-on approach by incorporating features of Problem and Project-Based Learning and at the same time cover the Learning Outcomes of the module. The new delivery approach included a series of motorsport-focused portfolio exercises of gradually increasing difficulty.

It is important to mention that the ARP presented in this dissertation has been partially inspired by new approaches in teaching and learning, which are in line with the educational philosophy described by Dr Marjo Kyllönen (Education Manager at General Education division in Helsinki) in TEDxHamburg in 2015 (Garner, 2015; TEDxHamburg, 2015). These relatively contemporary educational ideas are based on the so-called ‘phenomenon-based’ education where teachers deliver ‘topics’ rather than ‘subjects’. More specifically, the teaching and learning process focuses on covering selected topics in a holistic manner, in such a way that the learners’ creative thinking is triggered by having to interrelate diverse functions and concepts. This contemporary approach, among other contributions, focuses more on the learning rather than on the teaching process, and relates learning with real life / hands-on applications.
In Higher Education (HE), the equivalent of the ‘phenomenon-based’ teaching and learning approach could probably be the integrated multidisciplinary paradigm, where groups of learners from diverse disciplines are taught modules of common interest. As presented in Ezra and Nahmias (2015), for example, advanced mathematical programming via MATLAB software is being taught to a diverse audience ranging from psychology to computer science; the adoption of this interdisciplinary model could produce very encouraging outcomes in teaching and learning.

In line with the above, in this chapter, the special characteristics of Motorsport Engineering education will be presented and the attributes of Project-Based and Problem-Based Learning in Engineering education as well as the role of software in facilitating a contemporary approach in the teaching and learning of Engineering courses in HE will be discussed.

2.2 Motorsport Engineering courses in Higher Education and the role of the Data Acquisition Engineer in Motorsports

A Data Acquisition Motorsport Engineer is usually a member of a multidisciplinary team consisting of other engineers, technicians and mechanics. Motorsport Engineers handle big sets of data extracted from the sensors of a racing car, often with incomplete information, and must overcome challenging engineering problems within tight deadlines and under adverse circumstances in order to reach informed decisions (Radford et al., 2006) and provide specialist advice to other team members. Therefore, a comprehensive HE Motorsport Engineering course should adopt and incorporate characteristics of the motorsport profession in its delivery, so that graduates acquire both theoretical and practical knowledge and a range of valuable transferrable employability skills such as communication, teamwork, time management, project management etc.

The following elements are common to all engineering courses: (i) theoretical knowledge and understanding of the relevant modules, (ii) a strong experimental / hands-on element in order for the students to apply the acquired theoretical knowledge, (iii) experiential features enabling the learner to develop practical skills and knowledge, thus becoming critical and independent thinkers and (iv) computational / software features where the students enrich their knowledge and
understanding by modelling systems and developing simulations (Radford et al., 2006).

The incorporation of experimental and computational elements is particularly challenging in Motorsport engineering courses, because not only do they share common areas with the Mechanical and Electrical / Electronic engineering courses thus, meaning that they require a wide range of hardware facilities and software and additionally, they need to use specialised laboratories and gain hands-on experience from racetrack activities (Meechan, 2006; Radford et al., 2006).

However, it is essential that Active Learning is promoted throughout the delivery of Engineering courses including Motorsport courses as well. Engineering modules which convey a strong hands-on element could be delivered efficiently through either the Project-based Learning (PJL) or the Problem-based Learning (PBL) approach (Al-Zubaidy et al., 2016; Hanna et al., 2006).

2.3 Project-Based Learning (PJL) and Problem-Based Learning (PBL) in Engineering Education

Project-Based (PJL) and Problem-Based Learning (PBL) are student-centred learning models which have been utilised by different educational disciplines and at different levels. PJL could be categorised in three distinct areas, namely: 1) Assignment projects, 2) Subject projects and 3) Problem projects. PJL and PBL share many common features: they are application-oriented, focus on real-case scenarios, learners are usually encouraged to collaborate and to research information through various sources, teachers facilitate rather than direct the learning process utilising a constructivist approach and often there could be more than one answers to the project / problem investigated. Thus, both the PBL and PJL approaches are closely interrelated and are focusing primarily on the learning rather than on the teaching aspect (Mills and Treagust, 2003).

A few differences between the PJL and PBL approaches could be summarised as follows: (i) PJL aims towards the delivery of a final product / design, whereas PBL aims towards solving a problem usually based on a real-world scenario, (ii) PJL often covers more teaching sessions compared to the PBL, (iii) PJL is related more to the application of knowledge rather to its acquisition, with which the PBL
approach is more concerned, (iv) PJL is more closely related to subjects such as Mathematics and Science applied in Engineering, often requiring management of resources, time (and people in case it is a group-oriented project) and (v) PBL requires a process-oriented supervision whereas, PJL a product-oriented supervision (Ahmed et al, 2015; Mills and Treagust, 2003).

Both the PJL and PBL approaches aim to develop knowledge in relation to the current work practice in the field that the project / problem focuses on as well as capabilities in relation to problem solving, creative and critical thinking, reviewing and documenting (Al-Zubaidy et al, 2016; Luo, 2015). A PJL or a 'mixed' model is more appropriate for the delivery of engineering education, aiming towards developing a more professional environment, compared to the traditionally adopted lecture-centred teaching and learning model; the mixed model comprises elements of the PJL as well as the traditional teaching and learning approach (Luo, 2015).

The PBL and PJL approaches in relation to the engineering curriculum have been partially formalised through the ‘Conceiving — Designing — Implementing — Operating (CDIO)’ educational framework (Al-Zubaidy et al, 2016). CDIO is an international educational framework focusing on the engineering fundamentals, serving as a guide for curriculum planning and outcome-based assessment. It is important to mention that a diverse range of educational providers participate in the CDIO initiative, from research-led Universities to local colleges, with all of them adopting the CDIO concept for developing real-world systems and products (CDIO, 2017). PJL is related to the constructivist pedagogical approach where the learner utilises an inquiry-based approach and works on issues / questions that are real and are related to the topic which they study. In this process, the learners need to investigate, sometimes in-depth, in order to find answers to questions and manage to complete the tasks assigned (Al-Zubaidy et al, 2016; Milentijevic et al., 2008).

One key aspect associated with the inclusion of PJL in Engineering courses is the positive relation between ‘Active Learning’ through hands-on experience with student retention in Engineering courses. Engineering students are particularly interested in courses which can bridge the gap between theory and application and that enable them to solve real problems which are related to their field of study (Turkmen et al, 2012). However, the lack of modules involving projects where the learners must design and develop a system / product as well as the lack of connection between math and science principles with engineering applications are
important factors that cause many students to drop out of their engineering courses after the first year of their studies. Thus, it is important that modules which incorporate PJL and PBL to be included in the first semesters of the engineering courses (Hanna et al., 2006).

Another key aspect in relation to the necessity for inclusion of PJL in the curriculum of HE engineering courses in the UK has to do with the accreditation requirements set by the Engineering Council UK (ECUK) which is the regulatory body where Professional Bodies such as the Institution of Mechanical Engineers (IMechE) and the Institution of Engineering and Technology (IET) belong to (Al-Zubaidy et al, 2016). The Engineering Council’s UK Standard for Professional Engineering Competence (UK-SPEC) (Engineering Council, 2017b) sets out certain areas related to the Competence and Commitment Standard required for professional registration, according to which, amongst others, Chartered Engineers should:

“A. Use a combination of general and specialist engineering knowledge and understanding to optimise the application of existing and emerging technology.
B. Apply appropriate theoretical and practical methods to the analysis and solution of engineering problems.”

Similarly, two out of the five areas related to the Competence and Commitment Standard for Incorporated Engineers suggest that they:

“A. Use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology.
B. Apply appropriate theoretical and practical methods to design, develop, manufacture, construct, commission, operate, maintain, decommission and re-cycle engineering processes, systems, services and products.” (Engineering Council, 2017a; Engineering Council, 2017c).

Hence, one can observe that for both Chartered as well as Incorporated Engineers, the areas related to the ‘Competence and Commitment Standard requirements’ involve the application of existing and emerging technology as well as the application of appropriate theoretical and practical methods. These requirements point out the necessity to incorporate PJL / PBL in the engineering courses for accreditation purposes.

Furthermore, the ‘Competence and Commitment Standard for Chartered and Incorporated Engineers requirements’ include skills which are closely related to the
‘Assessment and Teaching of 21st Century Skills (ATC21S)’ project, an international project funded by Cisco Systems Inc., Intel Corporation and Microsoft Corporation and managed by the University of Melbourne (Melbourne Graduate School of Education, 2017; Griffin and Care, 2015). One of the project’s aims was to identify a set of skills in relation to the ‘competent graduate’. The skills identified included critical thinking and problem-solving as well as the necessity for Information & Communications Technology (ICT) literacy. The competent graduates, apart from being experts in their field, should also be expert learners; this means that they should be able to use previously acquired knowledge in order to develop new knowledge within a new topic, which would indicate that the students were evolving into independent and autonomous learners (Moroney et al., 2016). Similar learning objectives to the above are proposed by the Accreditation Board for Engineering and Technology (ABET) which is an international accreditation body widely recognised by Universities in the United States of America (Elsaiah and Jansson, 2016).

It is important to mention that alongside PJL / PBL, the ‘Portfolio-Centred Curriculum’ encapsulates similar attributes to those mentioned above. Specifically, some of the features of the portfolio-centred curriculum may be summarised as follows: (i) close relationship between coursework and experiential learning which enhances student motivation and confidence regarding their chosen field of study, (ii) enhancement of course learning by incorporating contextual and integrative experiences, (iii) combination of traditional with practice-oriented learning methods which enhances student engagement, (iv) enablement of learners to develop interests and knowledge within their field and to put into practice what they learn, (v) development of metacognitive skills thus, enabling students to track their learning process (The University of Rochester, 2013).

2.4 PJL and PBL in Motorsport Engineering Education

The PJL approach is being applied across many HE motorsport courses worldwide, which can be clearly demonstrated through the setting up of student teams that participate in national and international educational engineering competitions.

A typical example is the ‘Sunswift’ project at the University of New South Wales, which focuses on the design and development of vehicles that use solar and electric
power and compete in the World Solar Challenge rally on a biannual basis. The Sunswift project has been running entirely by students for more than 20 years and is a valuable tool, not only for obtaining discipline-specific scientific knowledge but also to apply it effectively in order to solve real design problems in engineering. The Sunswift project has played a key role in the professional development of the learners who have participated in it (UNSW, 2017; Smith et al., 2015).

Other examples include Universities’ participation in educational engineering competitions. The ‘Formula SAE’ competition was launched in 1981 by the Society of Automotive Engineers (SAE), leading to the launch of associated events internationally. For example, ‘Formula Student’ (FS) competition is managed by the Institution of Mechanical Engineers (UK) and takes place each year since 1998, having become Europe’s most established educational engineering competition (Institution of Mechanical Engineers, 2017a).

During the ‘Formula Student’ (FS) event, student racing teams from various HE institutes are asked to design, build and compete with a Formula-style racing car. Each racing car as well as the student teams are assessed by specialists from industry in a series of static and dynamic events, where static events are focusing on the business and design aspect, whereas dynamic events are focusing on competitive activities such as acceleration, fuel economy, endurance etc. (Michigan Engineering, 2017; Ni et al., 2016; Black, 2015). FS is ideal for PJL / PBL since it provides a lot of opportunities for the students to get involved in real-life projects, meet tight deadlines and familiarise themselves with high level industrial standards and strict specifications.

All the aforementioned projects could be incorporated in the motorsport engineering course curriculum and include a wide variety of tasks and activities, encompassing the features of PJL and providing students with the opportunity “to test, demonstrate and improve their capabilities to deliver a complex and integrated product in the demanding environment of a motorsport competition”, while facilitating their transition “from university to the workplace” (Institution of Mechanical Engineers, 2017b).

2.5 The role of MATLAB software in Higher Education Engineering courses
One of the main tools to facilitate the ‘learning by doing’ concept in HE is the use of relevant learning technology in order to integrate conceptual learning with the related applications (The University of Rochester, 2013). A very important teaching and learning tool in HE Engineering and Technology courses is the use of software which is utilised for programming, simulations, computing etc. MATLAB is probably the most popular software / programming language in HE Engineering education thanks to its user-friendly and intuitive features in relation to the introduction of mathematical expressions, vectors, matrices and functions for data analysis / processing and signal visualisation; MATLAB software focuses on the whole range of applications related to Mathematics, Programming and Visualisation (Mathworks, 2017c).

MATLAB is widely utilised in Pure Mathematics and Engineering Mathematics modules as well as in modules which require mathematical modelling; the aim of mathematical modelling is to describe a real-world application or system through mathematics (Toews, 2012). MATLAB software could be utilised as a Computer Algebra System (CAS) for modules that require simulations and model-based design. It is also used in modules that require programming and visualisation, where programming could be necessary in order to process / analyse a signal as well as to visualise it during the intermediate and final processing stages (Efe, 2016; Nyamapfene and Lynch, 2016).

It is important to mention that the successful utilisation of software as a teaching and learning tool often depends on the positive inclination of the teacher towards the software. Hence, the successful utilisation of CAS-assisted teaching often depends on the teacher’s conception that software is related to deep and rigorous mathematical thinking, a conception which could originate from their own research (Nyamapfene and Lynch, 2016).

Therefore, MATLAB is a useful tool for putting mathematics in the context of engineering modules or, in other words, to relate mathematics with engineering applications (Zhu et al., 2015; Marozas and Dumbrava, 2010). The simulation and visualisation capabilities of MATLAB assist learners to identify patterns, relationships and trends in data. However, to fully utilise the capabilities of MATLAB, the learners need to develop their knowledge on the use of the programming language.
The use of engineering software in general gives to the learners the opportunity to apply their knowledge in real-life problems and projects however, it is important to mention that teachers are required to adapt the module material in order to include the software and that certain parameters need to be considered when integrating software in the HE Engineering curriculum (Cheah et al., 2016; Bin Azman, 2005). Engineering software helps learners to develop their understanding on engineering concepts and thinking, to develop technical skills, to explore, experiment with and visualise engineering concepts through the 2-D (two-dimensional) and 3-D (three-dimensional) plotting and animation functions and thus, it is a useful tool which enhances the learning experience and improves learners’ motivation.

On the other hand, there may be some weaknesses and threats in relation to the utilisation of software in engineering education, as described in the SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis presented in Nyamapfene and Lynch (2016) and Efe (2016). Specifically, some students may underestimate the importance of the mathematics and physics background that an engineering graduate should have; it is easy by using software to alter certain parameters and repeat a process / simulation which may lead learners to adopt the ‘trial and error’ philosophy (Efe, 2016). These weaknesses and threats stem from the fact that software has a lot of processes / functions already developed for the user. The learner needs to have understood each step of the process and the background theory before utilising any ready-built process / function available by the software. The aforementioned weaknesses and threats should be considered when the teacher incorporates robust software tools in the curriculum of a module.

2.6 MATLAB software, Active Learning, PJL, PBL and their relationship with Motorsport Engineering education

The utilisation of MATLAB software for facilitating Active Learning through Project-based and Problem-based strategies has been reported in many research articles (Hoffbeck et al., 2016; Song et al., 2016; Frank and Roeckerath, 2015). However, it would be important for learners to gain an initial understanding of the basic concepts and functions in relation to MATLAB software through an introductory / short module.
For example, in the Faculty of Electrical Engineering and Information Technology in Bratislava an introductory MATLAB course is delivered to the learners during semester 2 of Year 1 in order for them to learn the basic principles and skills of MATLAB programming. During each lecture, a certain topic is introduced and discussed, and relevant exercises are being solved using MATLAB, while the students are assessed via weekly evaluation tasks. The tasks given to the students are developed in such a way that the learners are able to complete them in less than 90 minutes. The learners utilise the MATLAB reference manual which includes all functions that might be useful (Blaho et al., 2012). The advantages of this delivery method include that the students learn to work under strict time constraints and do not have to submit any homework. The disadvantages are that the teaching and learning experience is focusing primarily on the assigned tasks, the time constraint for finishing the task may cause stress and the students cannot be assessed when they miss the weekly evaluation tasks (Blaho et al., 2012).

Moreover, MATLAB software forms an essential part of Mathematical modules in institutes with different educational profiles such as the University College London (UCL) and Manchester Metropolitan University (MMU). In particular, MATLAB software assists learners to explore their discipline focusing on problems they consider authentic by utilising mathematical knowledge for real-world applications (Nyamapfene and Lynch, 2016). Similar conclusions could be relevant for engineering courses since most engineering-focused courses require solid knowledge and understanding of mathematics / applied mathematics.

MATLAB software can also be utilised for the promotion of active learning by introducing the learners in computer programming and engineering-related applications through lab exercises and projects. Specifically, MATLAB has been utilised by Mechanical, Civil and Electrical Engineering students at the University of Portland, Oregon, USA, as a tool for active learning. After a brief introduction by the teacher, the students worked on tasks applying their programming skills on specific engineering problems; each project task required three or four class sessions to be completed. The learners’ feedback was positive, although some of them found the module difficult and would prefer to have been provided with more instructions prior to starting the given tasks (Hoffbeck et al., 2016).

MATLAB has been utilised for Active Learning by many HE institutes worldwide, such as the Queen’s University Belfast (Müller, 2003), the College of Engineering of
Michigan State University (Mathworks, 2017a), the Mechanical Engineering department of the Indian Institute of Technology Delhi (MathWorks, 2013); it has been reported that the learners’ interest in the modules where MATLAB was utilised had been considerably enhanced.

In Motorsport Engineering, in particular, the strong relation between MATLAB software and Active Learning through PJL / PBL is underlined through the creation of the ‘MATLAB and Simulink Racing Lounge’ (MathWorks, 2017d); MathWorks, the company which has created MATLAB, has developed this platform where field experts and students involved in student racecar competitions can present their work and exchange knowledge and expertise.

2.7 Summary

This chapter presents a literature review regarding students’ Active Learning process through Project-Based (PJL) and Problem-Based Learning (PBL) in Engineering Higher Education and in Motorsport education, in particular. Furthermore, the role of MATLAB software in Engineering education is explored as well as its relation to Project-Based (PJL) and Problem-Based Learning (PBL). The following chapters present the quantitative methods which have been utilised in order to measure how well the delivery approach adopted in this ARP has been received by the learners, and also whether there is a relation between the academic performance of students in Year 1 Mathematics and Science-related modules, which form the foundation for the Year 2 ‘Chassis Development and Telemetry (MSP5001)’ module, with their academic performance in this module.
CHAPTER 3 – Research Methodology

3.1 An Action Research Project (ARP) for the ‘Chassis Development and Telemetry’ module

As mentioned earlier, this dissertation is based on an Action Research Project (ARP) which was implemented during the academic year 2015-2016, focusing on the second-year module ‘Chassis Development and Telemetry (MSP5001)’. This module was selected for the ARP, as it is suitable for demonstrating to the students the challenges in combining theoretical knowledge with practice (Larminie and Martin, 2009).

One of the aims of this intervention was to familiarise the learners with methods of processing and analysing signals extracted from the sensors of racing cars and hence its scope was closely related with the responsibilities and professional requirements associated with the Racecar Data Acquisition Engineer role. A Racecar Data Acquisition Engineer acquires data from a racing car in the form of sensor signals, processes them (e.g. filters from noise) and then analyses the sensor signals to extract useful features that will enable them to make accurate observations and reach informed decisions.

A competent Data Acquisition Engineer in Motorsports should have knowledge of: (i) software / programming in order to process and analyse the sensor signals, (ii) hardware in relation to the installation and calibration of sensors which are installed in various positions of a racecar and (iii) engineering principles so as to be able to interpret the information acquired from the sensors (Segers, 2014).

The ARP aimed to support an active learning process through Project based learning (PJL) and Problem based learning (PBL) in order to facilitate and promote the learners’ independent and critical thinking towards becoming competent Data Acquisition Engineers. A series of hands-on software laboratory exercises were developed, forming a portfolio under a coherent theme, focusing on the analysis and processing of real sensor signals extracted from racing cars. The visualisation and analysis of these signals by the students through MATLAB software assisted them in making observations, drawing useful conclusions and reaching informed decisions in relation to the racing car and / or the driver.
During the 15 weeks of the academic semester, the students were given the following 6 exercises to prepare and deliver (an updated version of these exercises is available in Paraskevas and Mullis, 2018):

1. “Estimation of straight and corner parts of a racing circuit through the Speed Trace and the Engine Speed Trace (Revolutions Per Minute) signals of a racing car”

2. “Estimation of the proportion of straight and corner parts of a racing circuit through the histogram produced by the Speed Trace signal of a racing car”

3. “Find and discuss features which are extracted from the maxima and minima points of the Engine Speed trace signal of a racing car”

4. “Develop an algorithm aiming to locate the minima and maxima points on the Engine Speed trace signal of a racing car. Create a smoothed version of the Engine Trace signal and re-apply the developed algorithm”

5. “Estimation of the gear position of a racing car through the division of the Speed trace signal by the Engine Speed trace signal. Process and compare the estimated signal with the signal extracted directly from the gear position sensor”

6. “Develop the Traction Circle of a racing car through the Longitudinal and Lateral acceleration signals”

Every 2 to 3 weeks, a new exercise was given to the learners; theory in relation to the racecar sensors was delivered by the teacher and discussed with the learners, and relevant examples / cases would be solved and discussed. The theory and exercises were partially inspired by Segers (2014). In the teaching session following the submission of each portfolio exercise, the solution would be given to the learners and the students would receive group and individual feedback from the teacher regarding each exercise.

For each exercise, an MS Excel file was provided to the students containing data, i.e. the signals extracted from a racing car competing in a circuit. The exercises were small and manageable, and included a hands-on (software) part focusing on the visual representation and processing of real signals acquired from the sensors of a racing car (computational part); they also included one or more relevant theory questions, where the students had to relate the software output with the theoretical
knowledge delivered to them previously by the teacher and obtained through their own research.

The learners were asked to solve the exercises during the teaching session or within a strict deadline, as would happen in a real case scenario where the racecar engineer would have to draw conclusions and make decisions within certain time constraints (The submission deadlines ranged from 1.5 hours up to 2 weeks, depending on the difficulty level of each exercise). The learners were encouraged to work together and exchange ideas, although each student was responsible for submitting his/her own work. Towards the end of the Semester the students could rework and submit up to 3 exercises in which they had previously failed or obtained a very low mark. The resubmitted exercises would receive a capped mark.

The experimental, experiential and computational elements were covered through the implementation of a project/problem-based learning approach and the use of data acquired from actual race events. Moreover, for the computational part, MATLAB programming was used in all exercises in order to process, analyse or visualise these sensor signals (Radford et al., 2006). The answers / solutions of the portfolio exercises required, amongst others, the retrieval of previously acquired knowledge from Year 1 modules of the course, especially knowledge and understanding of the related areas of applied mathematics. Consequently, the learners had to apply previously acquired knowledge within a new educational context, thus promoting active learning (Kyriacou, 1992).

In general, the content, structure and submission time constraints of the portfolio exercises of the MSP5001 module aimed to simulate the motorsport environment within the HE framework. The Motorsport engineering students gained an understanding of the limits and assumptions in the capturing, processing, analysis and interpretation of data. The students were asked to interpret the information extracted from various channels or combination of channels but more importantly to identify sources of potential errors, understand and develop specialised methods / techniques in signal processing as well as understand the trade-offs in the processing of a signal (Larminie and Martin, 2009).
3.2 The incorporation of MATLAB software in NCME’s courses

As in Nyamapfene and Lynch (2016), learners became familiar with MATLAB software during the first year of the course; MATLAB was introduced to the BEng and BSc courses through a series of approximately 5 seminars each lasting for 1.5 hours; in these seminars, the basic concepts of MATLAB such as syntax, basic operations and plotting were introduced in order to equip students with the necessary programming and analysis skills for year 2 of their studies.

A similar approach in relation to the introduction and utilisation of MATLAB during Year 1 and Year 2 in NCME’s undergraduate courses has been adopted by the Faculty of Electrical Engineering and Information Technology in Bratislava (Blaho et al., 2012) as well as by other Higher Education institutes (Song et al., 2016). Note that MATLAB software is also utilised as part of other second and third year NCME modules and its use may be considered as an employability and transferable skill.

With regards to the delivery of the Year 2 ‘Chassis Development and Telemetry (MSP5001)’ module, students needed to apply their previous knowledge and skills for the processing, analysis and display of sensor signals through software. Specifically, the students submitted two MATLAB preparatory exercises during Semester 1 in order to refresh their knowledge from Year 1 and then six exercises during Semester 2 (ARP). These six exercises involved the utilisation of real signals extracted from the sensors of racing cars. Three of the six exercises could be re-submitted in case the students were absent, had failed to pass them or had achieved a very low mark; the mark of the resubmitted work was capped. The exercises delivered during Semester 2 were taking place on a 2 to 3-week basis and the students had to submit their work under strict deadlines. Note that each teaching session lasted for 1.5 hours.

In the weeks between the laboratory exercises’ submission, the teacher would either introduce the new topic for the following exercise or would be providing students with feedback and marks in relation to their performance in the previously submitted exercise. The assessment and feedback with regards to the MATLAB software laboratory exercises aimed to assist students in their learning and to measure their understanding and progress; it also aimed to help the teacher evaluate the effectiveness of the ARP as well as the module’s delivery.
3.3 Research Design and Data Collection for the ARP

When the second-year MSP5001 module ran for the first time (academic year 2014-15), the tutor identified the need for connecting further its theoretical and practical aspects, in order to enhance the learners' critical thinking skills and enable them to become more competent motorsport engineers. Hence, the tutor decided to design and implement an ARP in order to provide the learners with enhanced hands-on experience through the incorporation of Project-Based (PJL) and Problem-Based Learning (PBL).

Action Research is a process where the tutor aims to improve their teaching of certain topics / modules through actions informed by their observations and research (McNiff, 2013; Open University, 2005). The teacher initially identifies potential changes in order to improve their teaching regarding a certain module / topic and subsequently, he / she develops an action plan and puts it into practice. Then, the tutor evaluates the outcomes of the action plan and decides on whether he / she should adopt these changes (Infed, 2017; McNiff and Whitehead, 2006; Kember, 2000).

The three basic approaches in Action Research include the interpretive, the critical theoretic and the living theory approaches (McNiff and Whitehead, 2002). From an educational perspective, the interpretive approach focuses on the way that the students understand the teaching and learning process, the critical theory adopts a political approach and the living theory approach focuses on the perspective of the practitioners in relation to the teaching and learning process (McNiff and Whitehead, 2002).

In relation to the ARP conducted for this study:

- For the first Research Question outlined in chapter 1, the author will investigate whether a correlation exists between the students’ marks in the Mathematics and Science-related Year 1 modules and their marks in the Year 2 MSP5001 ARP, using the following data:

**The BEng and BSc students’ marks for the following modules:**
(i) ‘Chassis Development and Telemetry (MSP5001)’; Year 2 module, common for both the BEng and BSc students
Note that the cohort of learners who were selected as the sample for this ARP joined the BEng and BSc courses in academic year 2014-15, with BEng students attending the first-year modules (ii) and (iv) and BSc students attending (iii) and (v). They also attended the second-year module (i) (common BEng and BSc module) during academic year 2015-16.

A positivist approach is selected regarding RQ 1, with a view to provide strong evidence underpinning different patterns in relation to the learners’ academic profiles; it utilises only quantitative tools in order to explore the relation between the learners’ prior knowledge with their performance in the ARP’s portfolio exercises.

For the second Research Question outlined in chapter 1, the potential improvement of the delivery of the MSP5001 module through the intervention (ARP), introduced by the tutor, will be investigated. The responses in the MEQs, the tutor’s self-reflection and the informal feedback provided to the author, as well as the learners’ attendance and pass rates will be utilised for the analysis:

(a) the learners’ responses in the Module Evaluation Questionnaires (MEQs)

Module Evaluation Questionnaires (MEQs) are delivered to Higher Education students in the UK for each taught module, in order to provide their feedback in relation to the quality of the module delivered, the module organisation and the resources utilised, the assessment(s) related to the module and the feedback provided by the tutor (Aston University, 2017; King’s College London, 2017; The University of Sussex, 2017). The MEQs delivered to learners at the University of Bolton consist of sixteen questions, where students need to reply by selecting one of the following options: ‘Strongly Disagree’, ‘Disagree’, ‘Agree’, ‘Strongly Agree’ or ‘Not Applicable’ (The University of Bolton, 2015).

(b) informal feedback in relation to the intervention provided by the learners to the tutor
The tutor held an individual interview of up to 5-minutes’ duration with each learner who participated in the ARP. The learners were asked to describe the positive and the negative points in relation to the intervention and the overall experiences they obtained.

The informal feedback provided by the learners enhances the reliability and validity of the proposed method, assists on the explanation of the experimental outcomes thus, facilitating the triangulation of the research outputs (Perone and Tucker, 2003).

The utilisation of the learners’ responses to the MEQs and the informal feedback provided by the learners to the tutor is based on the interpretive approach.

**(c) learners’ attendance rates and pass rates** and

**(d) a self-reflection of the tutor in relation to the intervention.**

In order to develop the motorsport-focused portfolio exercises, the author collaborated with a colleague who is an expert in the motorsport industry to incorporate relevant contemporary knowledge and also, to acquire input from an expert regarding the content, scope and direction of the ARP. The role of the abovementioned critical friend was very important to the author in order to reflect on and confirm his assumptions with respect to the design, structure and content of the ARP (University of Huddersfield, 2018).

The self-reflection of the tutor is related to the living theory approach.

In general, RQ 2 incorporates quantitative analysis (i.e., the learners’ attendance and pass rates as well as the statistical analysis part with regards to the MEQs), which is based on the positivist approach, and is also influenced by the interpretive and the living theory approaches.

### 3.4 Quantitative methods for Data Analysis
With regards to the quantitative analysis, a brief description of the quantitative methods used to process and analyse the data, and the context within which they were selected are presented. An example for each method, alongside the corresponding hand calculations can be found in the Appendix (section V), since some of the readers may not be familiar with the mathematical / analytical implementation of these methods. Note that the hand calculation results presented in the Appendix have also been verified through MATLAB software.

Moreover, formal feedback forms (MEQs) and oral feedback provided by the learners in relation to this ARP were used, while the relevant ‘Information Sheet’, ‘Consent Form’ and ‘Research Ethics form’ were produced for compliance with the University’s regulations (See Appendix, sections I, II and III).

The quantitative methods used in this dissertation are described, namely: (i) the Pearson Product-moment Coefficient \((r)\) (*Correlation Coefficient*), (ii) the *k*-means clustering algorithm and (iii) the Wilcoxon rank sum test as well as the important concept of *Statistical Hypothesis Testing*.

Statistical hypothesis testing is a very important method of statistical inference. Hypothesis testing is used for identifying whether a relationship does or does not exist between two sets of data. The null hypothesis \((H_0)\) is a general or default position which states that there is no relationship between two data sets, whereas the alternative hypothesis \((H_1)\) states that there is a relationship between these two data sets. Statistical hypothesis testing is the procedure determining whether any relation between two data sets is statistically significant. The level of (statistical) significance corresponds to the probability of rejecting \(H_0\) when it is true. Statistical significance corresponds to the probability that the relation amongst two or more variables is not caused due to sampling error. Typically, the significance level for an experiment is selected to be 5% (ASK Academic Skills Kit, 2017; Penn, 2017a; Pelham, 2013; Molyn, 2012; Mansfield, 1986).

(i) The *Correlation coefficient* is a measure of the relationship between two variables (Papoulis, 1991). In chapter 4 of this work, the correlation coefficient was utilised in order to identify potential relations between the academic performance of BEng as well as BSc students in the Science, Mathematics and Programming-related Year 1 modules with their academic performance in the Year 2 ‘Chassis Development and Telemetry (MSP5001)’ module, based on the marks that learners
had achieved in the respective modules during Year 1 and Year 2. The conclusions drawn, and observations made correspond to a 5% (0.05) significance level.

Hence, in the experiments conducted using the Correlation Coefficient, the null hypothesis ($H_0$) corresponded to the case where there was no relationship between the marks that the learners achieved in Year 1 with the marks achieved in the MSP5001 Year 2 module irrespectively of the value of the Correlation Coefficient, whereas, the alternative hypothesis ($H_1$) stated that there was a relationship between these two data sets. The method for testing the significance of the Correlation coefficient was found by calculating the t-value utilising the t-distribution (Kenneth, 2017). Note that the t-distribution is used instead of the normal distribution when the standard deviation of the population is not known, and the size of the sample is less than 30 (Kreyzig, 1995).

(i) The *Pearson Product-moment Correlation Coefficient* ($r$) is a number which quantifies the relationship / correlation between two variables, and the Scatterplot is a plot which visually identifies whether there is a relationship between the two variables.

A Scatterplot is developed by locating the pair values of the two variables on the Cartesian coordinate system. An upward trend of the plotted pairs indicates a positive relationship between the two variables; when one variable increases, the other variable then increases as well, whereas, a downward trend of the plotted pairs indicates a negative relationship. Note that there are cases where there could be no trend, meaning that no relationship exists between the two variables.

The values of the Pearson product-moment coefficient, $r$, range from -1 to +1, where -1 and +1 imply negative and positive correlation, respectively. Values of $r$ which are close to 0 imply no correlation between the two variables (Molyn, 2012).

The mathematical formula which calculates the correlation coefficient, $r$, is:

$$ r_{xy} = \frac{s_{xy}}{\sqrt{s_{xx}s_{yy}}} \quad (1) $$

where
\[ S_{xx} = \sum_{i=1}^{n} x_i^2 - \frac{(\sum_{i=1}^{n} x_i)^2}{n} \]  
\( (2) \)

\[ S_{yy} = \sum_{i=1}^{n} y_i^2 - \frac{(\sum_{i=1}^{n} y_i)^2}{n} \]  
\( (3) \)

\[ S_{xy} = \sum_{i=1}^{n} x_i y_i - \frac{\sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n} \]  
\( (4) \)

\( r_{xy} \) is the correlation coefficient between variables \( x \) and \( y \), \( n \) is the sample / population size, \( i \) is the subscript of each data point and \( \sum \) is the summation operator.

(ii) The \textit{k-means clustering algorithm} aims to group data points into a certain group (cluster). As discussed in chapter 5 of this dissertation, the k-means clustering algorithm was utilised as a tool for identifying potential patterns in relation to the BEng and BSc students’ academic profiles and performance, based on the marks achieved in the Year 1 Mathematics and Science as well as in the Year 2 ‘Chassis Development and Telemetry (MSP5001)’ modules (Mathworks, 2017b; Webb, 2001).

(iii) The \textit{Wilcoxon rank sum test} was used as a tool for comparing the responses of the learners in the MEQs for the ‘Chassis Development and Telemetry (MSP5001)’ module with the responses in all the other modules delivered by the School of Engineering and by the University (Hole, 2017; Winner, 2017); this aimed to explore whether the implementation of the ARP developed for the MSP5001 module was favourably assessed by the learners (their opinions were more positive i.e. towards the Agree / Strongly Agree direction), i.e., to examine whether the students were more satisfied with the MSP5001 module as compared to the other modules delivered by the School and the University.

To conduct the experiments and perform the aforementioned comparison, the ‘Strongly Disagree’, ‘Disagree’, ‘Agree’ and ‘Strongly Agree’ responses were scaled as 1, 2, 3 and 4, respectively, as in a Likert scale, since Likert scale data is ordinal (The University of St. Andrews, 2017). Note that the Wilcoxon rank sum test, which is a non-parametric test, is appropriate for comparing the two groups of data (student’s responses) i.e., MSP5001 module vs. the School of Engineering modules.
and MSP5001 module vs. the University modules (Stefanowski, 2013; Bertram, 2008).

Note that a parametric statistical method assumes that the population is normally distributed and that the size of the sample is large, whereas the non-parametric statistical methods do not make assumptions on the distribution of the population or the size of the sample. In the parametric tests, the difference in the mean value among the groups of data compared is examined, whereas in the non-parametric tests the difference in the median - rather than the mean - value is examined (R Tutorial, 2017; Frost, 2015a; Kitchen, 2009).

As in the case of Correlation coefficient, a hypothesis test was conducted to determine whether the difference in the median value of the groups of data compared was statistically significant at a selected level.

Furthermore, note that in the experiments conducted for this work, the module marks and the MEQs of the whole population of students who attended the MSP5001 module during academic year 2015-16 was utilised. Hence, one could argue whether the statistical analysis methods should be different when analysing the entire population, as compared to the case where only a sample of this population is analysed. According to Professor Andrew Gelman at Columbia University (2009), an assumption that our population (students attending MSP5001 module during academic year 2015-16) forms a sample of a larger population could be made and thus, the same statistical analysis methods could be applied. In the case presented in this work, it could be assumed that the population we are focusing on is a sample of the wider population formed by students who will be attending the same module in the coming years.

3.5 Consent Form, Information Sheet and Research Ethics form

In order to conduct the experiments and obtain the results included in chapter 4, an Information Sheet and a Consent Form were developed and delivered to the students in line with the University’s procedures (The University of Bolton, 2018). The Information Sheet described to the students the aim and scope of this research project and how it was related with the author’s previous research work. Based on this information, the learners were asked to provide their consent for the researcher
to be able to utilise their assignment and examination results for the aforementioned modules as well as any form of feedback that they had provided regarding these modules (through Module Evaluation Questionnaires or otherwise) for his experiments and analysis. After reading the Information Sheet, the students who agreed with its content were asked to sign the corresponding Consent Form.

Furthermore, a Research Ethics form was filled in and signed by the researcher, his Supervisor and the Research Ethics Officer of the School of Education and Psychology. The aim of the Research Ethics form was to confirm that the research would be taking place according to the University of Bolton Code of Practice and to examine whether there were any ethical issues in relation to the way the research would be conducted. However, the provisional title of the project “The role of mathematical-related software as a tool for the transition towards active learning and critical thinking” in the aforementioned documents was changed to “The Utilisation of Project - Based and Problem - Based Curriculum for the transition towards Active Learning and Critical Thinking for Undergraduate Motorsport learners” as the author extended his research in other related areas, thus providing a more holistic approach (Note that copies of the Research Ethics form, the Information Sheet and the Consent form can be found in the Appendix (sections I, II and III); signed copies of the Consent Form are available upon request).

It is important to clarify that the participation of the learners in the actual ARP was not voluntary since it was not possible to ‘run’ in parallel two classes for the same module, one in which the intervention would take place and one in which it would not. Thus, the author acknowledges the ethical dilemma in relation to the non-voluntary participation of the students in this intervention. However, the author decided to implement the ARP because he strongly believed that it would be beneficial for the students in terms of the knowledge and skills they would acquire from it.

3.6 Summary

In this chapter, the Methodology tools utilised for this work are described in relation to an ARP which was developed with a view to enhance the learners’ independent and critical thinking through a series of portfolio exercises in the area of data acquisition for motorsport engineering. There is a brief description of the quantitative methods used as well as the context within which they were selected.
CHAPTER 4: Results

4.1 Introduction

In this chapter, quantitative analysis using the methods described in chapter 3 is being conducted, to help draw conclusions and make observations in relation to the efficiency of the ARP which was developed for the Year 2 ‘Chassis Development and Telemetry (MSP5001)’ module. The Correlation coefficient and the k-means algorithm are being used in order to identify potential relations between the academic performance of the students for selected Year 1 modules and the performance of the same students for the ARP of the Year 2 MSP5001 module. Moreover, the Wilcoxon rank sum test is being utilised in order to compare the levels of learners’ acceptance of the MSP5001 module with those of the School and University modules through the students’ responses to the University’s MEQs.

Find below a brief synopsis regarding the data utilised for the experiments conducted and presented in the following sections:

(a) The student cohort selected for the experiments consisted of the BEng in ‘Automotive Performance Engineering’ and the ‘BSc in Motorsport Technology’ students who commenced their undergraduate studies in academic year 2014-15 (Year 1).

Specifically, during academic year 2014-15, 7 students joined Year 1 of the BEng course and 13 students joined Year 1 of the BSc course. However, from the same cohort of students, 1 BEng student failed to continue in Year 2 and 5 BSc students failed to continue in Year 2 (academic year 2015-16). Thus, for the Scatterplots (section 4.2) as well as the Pearson Product-moment Coefficient experiments which identify potential relationships in the academic performance of the students between Year 1 and Year 2, the population number utilised for the experiments is 6 (= 7 - 1) BEng plus 8 (= 13 - 5) BSc students i.e., the students who proceeded from Year 1 to Year 2. The same modules and number of students have been utilised for identifying potential groups (clusters) based on the academic performance of the BEng and BSc students via the k-means algorithm.
(b) The Year 1 BEng and BSc modules used in this research to help identify potential relationships were the Mathematics and Science related modules. Specifically, for the BEng students, these modules include: (i) ‘Engineering Mathematics (MSP4007)’ and (ii) ‘Performance Engineering Sciences (MSP4006)’ while for the BSc students, the modules are: (i) ‘Applied Analytical Methods (MSP4005)’ and (ii) ‘Chassis and Electronic Principles (MSP4001)’. Modules MSP4007 and MSP4005 are focusing on Mathematics and modules MSP4006 and MSP4001 are focusing on Sciences.

Note that the aforementioned Year 1 modules were selected because their content is related to the ‘Chassis Development and Telemetry (MSP5001)’ module. Also, as mentioned in chapter 3, note that the MSP5001 module is assessed through a series of portfolio exercises.

(c) The data utilised for the Correlation coefficient and the k-means algorithm experiments comprise the marks which the students obtained for the Year 1 MSP4006, MSP4007 modules (BEng course) and the Year 1 MSP4001, MSP4005 modules (BSc course) delivered during academic year 2014-15, as well as the marks of the Year 2 ARP for the MSP5001 module, common in the BEng and BSc courses, which was delivered during the academic year 2015-16 (Semester 2).

(d) MATLAB software was delivered as part of the Year 1 MSP4006 (BEng) and MSP4001 (BSc) modules and was assessed through an exam question, and therefore, for certain experiments in sections 4.2 and 4.3, the mark for the MATLAB software exam question of the MSP4006 and MSP4001 modules has been used.

(e) In the Correlation coefficient and the k-means algorithm experiments presented in the following sections, when the term MSP5001 results is used, it corresponds to the marks which the learners obtained for the MSP5001 module during Semester 2 only i.e., during the ARP described in this dissertation.

(f) For all modules running during both Semester 1 and 2 of each academic year, the University of Bolton delivers the MEQs at the end of Semester 2. Consequently, the students’ responses to the MEQs reflect the opinion of the learners for both Semester 1 as well as Semester 2. Thus, in the experiments conducted utilising the MEQs regarding the MSP5001 module, the learners’ opinion reflected both Semesters rather than only Semester 2 when the ARP for MSP5001 took place.
(g) The methodology for developing the Scatterplots, the Pearson Product-moment Coefficient, the k-means algorithm and the Wilcoxon rank sum test have been presented in chapter 3 and the Appendix (section V).

4.2 Scatterplots and the Pearson Product-moment Correlation Coefficient (r)

The Scatterplot and the Pearson Product-moment Coefficient (Correlation coefficient) are utilised in order to identify and demonstrate potential correlations between the learners’ academic performance in selected Year 1 modules and their performance in the Year 2 MSP5001 module ARP. These quantitative tools are utilised for the analysis of RQ 1 (see chapter 1).

The upper and lower scatterplots in Figure 1 indicate a positive correlation between the marks of the Year 1 ‘Chassis and Electronic Principles’ MSP4001 module and the Year 2 ‘Chassis Development &Telemetry (MSP5001)’ module (ARP) for the BSc students. This positive trend holds when (a) the final mark, incorporating all marked assessments of the MSP4001 module is considered (Figure 1a), as well as when (b) only the MATLAB assessment (mark for the MATLAB exam question) of this module has been considered (Figure 1b). Note that Figure 1a includes 8 points (asterisks), because the number of the BSc students is 8; however, in Figure 1b, the number of points is 7 instead of 8 because there are two points on (0,0) i.e., two students were awarded 0 marks in the MATLAB assessment for module MSP4001 as well as for the MSP5001 module (ARP).
However, similar characteristic trends have not been identified between the academic performance in Mathematics or Science related BEng modules and the MSP5001 ARP. This can be confirmed by the results obtained from the calculation of the Pearson Product-moment Coefficient ($r$) between the students’ marks for the BEng Mathematics, BEng Science modules and the MSP5001 ARP (Table 1).

<table>
<thead>
<tr>
<th>Engineering Mathematics (MSP4007)</th>
<th>Performance Engineering Sciences (MSP4006)</th>
<th>Performance Engineering Sciences (MSP4006) - MATLAB assessment</th>
<th>Average marks of MSP4007 &amp; MSP4006</th>
<th>Average marks of MSP4007 &amp; MSP4006 - MATLAB assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chassis Development &amp; Telemetry (MSP5001) ARP – BEng</td>
<td>0.3183</td>
<td>0.1134</td>
<td>0.0414</td>
<td>0.2630</td>
</tr>
</tbody>
</table>

*Table 1: Correlation Coefficient between the marks of the BEng Year 1 modules and the marks of the Chassis Development and Telemetry (MSP5001) ARP.*

Regarding the BSc course, the positive trends presented in Figures 1a and 1b have been quantified through the Pearson Product-moment Coefficient ($r$) and its value of 0.9123 (see Table 2, column 2) and 0.9200 (Table 2, column 3) indicates a very strong correlation.

<table>
<thead>
<tr>
<th>Applied Analytical Methods (MSP4005)</th>
<th>Chassis and Electronic Principles (MSP4001)</th>
<th>Chassis and Electronic Principles (MSP4001); MATLAB assessment</th>
<th>Average marks of MSP4005 &amp; MSP4001</th>
<th>Average marks of MSP4005 &amp; MSP4001; MATLAB assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chassis Development and Telemetry (MSP5001) ARP – BSc</td>
<td>0.6993</td>
<td>0.9123 (Level of Significance (L.S.) $\alpha = 0.05$ (see Fig. 1a))</td>
<td>0.9200 (L.S. $\alpha = 0.05$ (see Fig. 1b))</td>
<td>0.8586 (L.S $\alpha = 0.05$) (see Fig. 2a)</td>
</tr>
</tbody>
</table>

*Table 2: Correlation Coefficient between the marks of the BSc Year 1 modules and the marks of the Chassis Development and Telemetry (MSP5001) ARP.*
Similarly, very strong \((0.8 < r \leq 1)\) or strong \((0.6 < r \leq 0.8)\) correlations at the \(\alpha = 0.05\) Level of Significance have been identified between:

- The MSP5001 ARP marks and the average marks of the MSP4005 & MSP4001 modules (Figure 2a).

**Notes:**
*Note 1*: The average mark is obtained by adding together the mark of MSP4005 and the mark of MSP4001 and then divide by two, a process which is repeated for each student.

*Note 2*: Since both MSP4005 and MSP4001 are BSc modules, the number of asterisks in Figure 2a is eight (8 students), as expected.

- The MSP5001 ARP marks and the average marks of the MSP4005 & MSP4001 (MATLAB assessment only) modules (Figure 2b).

**Note:**
As in the previous case, since both MSP4005 and MSP4001 are BSc modules, the number of asterisks in Figure 2b is eight, as expected.
The MSP5001 ARP marks and the marks of the combination of the BEng Science (MSP4006) with the BSc Science (MSP4001) modules (Figure 3a).

Notes:
Note 1: The combination of the MSP4006 (BEng module) with the MSP4001 (BSc module) is obtained by developing a vector (i.e. set of data points) which comprises the marks of the two modules i.e., the marks of MSP4006 (6 BEng students) followed by the marks of MSP4001 (8 BSc students) hence:
Dataset 1: [MSP4006-1, MSP4006-2, ..., MSP4006-6, MSP4001-1, ..., MSP4001-8]
Then, a second dataset (Dataset 2) comprising the marks of the MSP5001 ARP is developed, including the marks of the same 14 students (= 6 BEng + 8 BSc) hence:
Dataset 2: [MSP5001-1, MSP5001-2, ..., MSP5001-13, MSP5001-14].
Then, the correlation coefficient, r, between Dataset 1 and Dataset 2 is calculated.

Note 2: Each mark from Dataset 1 corresponds to the mark of the same student from Dataset 2.

Note 3: Since Dataset 1 and Dataset 2 comprise 14 data points in total, the number of asterisks in Figure 3a equals fourteen, as expected.
The MSP5001 ARP vs. the combination of the Science BEng (MSP4006, MATLAB assessment only) with the Science BSc (MSP4001, MATLAB assessment only) modules (Figure 3b).

**Notes:**

*Note 1:* The combination of MSP4006 (MATLAB assessment only) with MSP4001 (MATLAB assessment only) is obtained through the method described in the previous paragraph.

*Note 2:* Since MSP4006 (6 students) is combined with MSP4001 (8 students) the number of asterisks in Figure 3b should be fourteen. However, the number of asterisks is 13 rather than 14 because there are two asterisks on (0,0) which correspond to the two students who were awarded 0 marks for the MATLAB assessment for MSP4001 as well as for the MSP5001 ARP.

*Note 3:* The value of $r$ as well as the corresponding L.S. can be found in Table 3.

<table>
<thead>
<tr>
<th>Combination of average marks of:</th>
<th>Combination of average marks of:</th>
<th>Combination of average marks of:</th>
<th>Combination of average marks of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chassis Development and Telemetry (MSP5001) ARP – BEng &amp; BSc</td>
<td>MSP4007 &amp; MSP4005 modules</td>
<td>MSP4007 &amp; MSP4006 (MATLAB assessment) with MSP4001 (MATLAB assessment) modules</td>
<td>MSP4007 &amp; MSP4006 (MATLAB assessment) with MSP4001 (MATLAB assessment) modules</td>
</tr>
<tr>
<td>0.3397</td>
<td>0.8510 (at the $\alpha = 0.05$ L.S.) (see Fig. 3a)</td>
<td>0.8995 (at the $\alpha = 0.05$ L.S.) (see Fig. 3b)</td>
<td>0.6585 (at the $\alpha = 0.05$ L.S.) (see Fig. 4a)</td>
</tr>
</tbody>
</table>

*Table 3: Correlation Coefficient between BEng & BSc Year 1 modules and the Chassis Development and Telemetry (MSP5001) ARP*
• The MSP5001 ARP and the combination of: (a) the average marks of the BEng MSP4007 and MSP4006 modules [6 students] with (b) the average marks of the BSc MSP4005 and MSP4001 modules [8 students] (Figure 4a).

Notes:
Note 1: The combination and the average marks of the aforementioned modules are obtained through the methods described in the previous paragraphs.

Note 2: Since the BEng modules MSP4007 and MSP4006 (6 students) are combined with the BSc modules MSP4005 and MSP4001 (8 students) hence, the number of asterisks in Figure 4a is fourteen, as expected.

• The MSP5001 ARP and the combination of: (a) the average marks of the BEng MSP4007 and MSP4006 (MATLAB assessment only) modules with (b) the average marks of the BSc MSP4005 and MSP4001 (MATLAB assessment only) modules (Figure 4b).

Notes:
Note 1: Since the BEng modules (6 students) are combined with the BSc modules (8 students) the number of asterisks in Figure 4b is fourteen, as expected.

Note 2: The value of $r$ as well as the corresponding L.S. can be found in column 5 of Table 3.
4.3 The k-means algorithm

The k-means algorithm was utilised in order to detect potential clusters corresponding to the learners’ academic profiles, within the BEng & BSc groups of students who attended the MSP5001 ARP; the k-means algorithm was used for the analysis of RQ 1 outlined in chapter 1. Thus, a series of software experiments were conducted, and the most representative results are presented here.

Figure 5 presents the clustering of the BEng and the BSc students based on the marks they obtained in the combination of: (i) BEng and BSc Mathematics (Year 1 MSP4007 BEng module and Year 1 MSP4005 BSc module), (ii) BEng and BSc Science (Year 1 MSP4006 BEng module and Year 1 MSP4001 BSc module) and (iii) Chassis Development and Telemetry ARP (Year 2 MSP5001 common BEng & BSc module). The aforementioned combination (dataset) forms a matrix consisting of three columns and fourteen rows where the three columns correspond to the: (a) Mathematics (BEng & BSc), (b) Science (BEng & BSc) modules and (c) ‘Chassis Development and Telemetry’ (BEng & BSc) ARP marks, respectively, and each row
corresponds to each one of the fourteen students. In Figure 5, the red dots represent the BSc students (Cluster 1), the blue dots the BEng students (Cluster 2) and the black dots the centroids of these two clusters. From this figure, it can be observed that there are 7 red dots and 7 blue dots instead of 8 red dots (BSc students) and 6 blue dots (BEng students). This means that there was only one mis-clustered individual i.e., only one BSc student was misclustered as a BEng student.

Figure 5: Clustering based on the BEng & BSc Mathematics (MSP4007, MSP4005), Science (MSP4006, MSP4001) and Telemetry (MSP5001, ARP) modules

Figures 6 to 9 present the clustering within the group of the BSc students only. Specifically, Figure 6 presents the BSc students’ clustering based on the marks that they obtained in the combination of: (i) Mathematics (Year 1 MSP4005 module), (ii) Science (Year 1 MSP4001 module) and (iii) Chassis Development and Telemetry (Year 2 MSP5001 module) ARP (Case 1).

Figure 7 presents the BSc students’ clustering based on the marks that they obtained in the combination of: (i) Mathematics (Year 1 MSP4005 module), (ii) Science (Year 1 MSP4001 module, MATLAB assessment only) and (iii) Chassis Development and Telemetry (Year 2 MSP5001 module) ARP (Case 2).
Figure 6: Clustering based on the BSc Mathematics (MSP4005), Science (MSP4001) and Telemetry (MSP5001, ARP) modules

Figure 7: Clustering based on the BSc Mathematics (MSP4005), Science - MATLAB assessment only (MSP4001) and Telemetry (MSP5001, ARP) modules

Figure 8 presents the BSc students’ clustering based on the marks that they obtained in the combination of: (i) Mathematics (Year 1 MSP4005 module) and (ii) Chassis Development and Telemetry (Year 2 MSP5001 module) ARP (Case 3).

Figure 9 presents the BSc students’ clustering based on the marks that they obtained in the combination of: (i) Science (Year 1 MSP4001 module) and (ii) Chassis Development and Telemetry (Year 2 MSP5001 module) ARP (Case 4).
Figure 8: Clustering based on the BSc Mathematics (MSP4005) and Telemetry (MSP5001, ARP) modules

Figure 9: Clustering based on the BSc Science (MSP4001) and Telemetry (MSP5001, ARP) modules

In each of the Figures, from Figure 6 to Figure 9, two clusters were identified; one comprising 2 dots and the other comprising 6 dots. The two dots correspond to the two BSc students who failed the MSP5001 ARP, whereas the group of 6 dots corresponds to the BSc students who successfully passed the MSP5001 ARP.

The clustering results presented in Figure 5 to Figure 9 have been summarised in Table 4 below:
<table>
<thead>
<tr>
<th>Clustering of BEng and BSc students (Figure 5)</th>
<th>Clustering of BSc students – Case 1 (Figure 6)</th>
<th>Clustering of BSc students – Case 2 (Figure 7)</th>
<th>Clustering of BSc students – Case 3 (Figure 8)</th>
<th>Clustering of BSc students – Case 4 (Figure 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of ‘mis-clustered’ students</td>
<td>1 out of 14</td>
<td>0 out of 8</td>
<td>0 out of 8</td>
<td>0 out of 8</td>
</tr>
</tbody>
</table>

Table 4: Summary of the clustering results obtained through the k-means algorithm

4.4 Wilcoxon rank sum test and MEQs

The Wilcoxon rank sum test, introduced in chapter 3, was utilised in order to identify whether the feedback of the learners who had experienced the delivery method of the MSP5001 module was more positive, compared to the learners’ feedback regarding the other modules delivered by the School of Engineering and by the University of Bolton; the Wilcoxon rank sum test was used for the analysis of RQ 2 outlined in chapter 1. The learners’ feedback was provided via the Module Evaluation Questionnaires (MEQs) for the ‘Chassis Development and Telemetry (MSP5001)’ module as well as the rest of the modules delivered by the School of Engineering or by the University, and was used in order to make comparisons in terms of teaching, learning, delivery, feedback and the other aspects outlined in the MEQs.

The size of the sample / number of students utilised for the Wilcoxon rank sum test corresponds to the number of students who responded to the MEQs. Specifically, there were 10 respondents for the MSP5001 module, 1,103 respondents for the School of Engineering and 7,373 respondents for the University. Note that the number of respondents for the MSP5001 module is 10 rather than 14 (total number of students enrolled in the module), because 10 is the number of learners who replied to the MSP5001 MEQ.

The MEQ delivered to the learners by the University of Bolton comprises the following sixteen statements:
1. ‘The written information provided about the module was clear and accurate’
2. ‘The module content was up to date’
3. ‘The module content met my expectations’
4. ‘Module delivery was well organised’
5. ‘There was a good balance of learning and teaching methods used in the module’
6. ‘I was encouraged to actively participate during the module’
7. ‘The learning materials used in the module were good’
8. ‘The library resources provided for the module met my learning needs’
9. ‘The facilities and equipment provided for the module met my learning needs’
10. ‘The teaching room(s) used was (were) good’
11. ‘The workload associated with the assignments/coursework was manageable’
12. ‘The assignments (and any exams) were relevant’
13. ‘I received grades and feedback on my assignments within the published timescale’
14. ‘The feedback I have received on my progress has been helpful’
15. ‘The tutor(s) was (were) helpful’
16. ‘Overall, I was satisfied with this module’

For each of the statements above, the MEQ respondents had to select one out of the following five choices: ‘Strongly Agree’, ‘Agree’, ‘Disagree’, ‘Strongly Disagree’ and ‘Not Applicable’. The author quantified the responses of the learners regarding the aforementioned five choices, as follows: ‘Strongly Agree’: 4, ‘Agree’: 3, ‘Disagree’: 2, ‘Strongly Disagree’: 1, ‘Not applicable’: 0. The quantification of the responses is a necessary step in order to utilise the Wilcoxon rank sum algorithm.

The ‘Wilcoxon rank sum algorithm’ was used in order to test whether there was an increase in the median value of the students’ responses for each of the Module Evaluation Questions regarding the ‘Chassis Development and Telemetry (MSP5001)’ module, as compared with the median value of the learners’ responses to the Module Evaluation Questions regarding the School of Engineering and the University’s modules; a higher median value (i.e., a shift towards the ‘Strongly Agree’ direction) of the MEQ responses for MSP5001 compared to the MEQ responses for modules of the School of Engineering and the University at a
certain level of significance, corresponds to the rejection of the null hypothesis \((H_0)\). Note that the hypothesis tests conducted are right-tailed at a 2.5% level of significance. The tests are right-tailed (directional hypothesis) since the author assumed that the median values of the MEQ responses of the MSP5001 module were higher than the median values of the MEQ responses of the School of Engineering modules and of the University modules (Penn, 2017a).

Based on the experimental results obtained through the Wilcoxon rank sum algorithm (Table 5), the following observations are obtained:

i) Rejection of the null hypothesis (i.e., higher median value of the MSP5001 MEQ responses as compared to the School of Engineering modules’ MEQs) for the following statements: 3, 6, 7, 10, 11, 12, 13, 14, 15 and 16. The same result was obtained, irrespective of whether the ‘Not Applicable’ response had been included or not in the experiments.

ii) Rejection of the null hypothesis (i.e., higher median value of the MSP5001 MEQ responses as compared to the University modules’ MEQs) for the following statements: 3, 10, 11, 12, 13, 14, 15. The same results were obtained irrespective of whether the ‘Not Applicable’ response had been included or not in the experiments.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>(H_0) : not rejected</td>
<td>(H_0) : not rejected</td>
</tr>
<tr>
<td>Question 2</td>
<td>(H_0) : not rejected</td>
<td>(H_0) : not rejected</td>
</tr>
<tr>
<td>Question 3</td>
<td>(H_0) : rejected</td>
<td>(H_0) : rejected</td>
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<tr>
<td>Question 4</td>
<td>(H_0) : not rejected</td>
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<tr>
<td>Question 5</td>
<td>(H_0) : not rejected</td>
<td>(H_0) : not rejected</td>
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<tr>
<td>Question 6</td>
<td>(H_0) : rejected</td>
<td>(H_0) : not rejected</td>
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<td>Question 7</td>
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<td>Question 13</td>
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<tr>
<td>Question 15</td>
<td>$H_0$ : rejected</td>
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</tr>
<tr>
<td>Question 16</td>
<td>$H_0$ : rejected</td>
<td>$H_0$ : not rejected</td>
</tr>
</tbody>
</table>

*Table 5: Hypothesis testing; MSP5001 vs. School of Engineering MEQs (column 2) and MSP5001 vs. University MEQs (column 3).*

### 4.5 Student feedback on the ARP

At the end of academic year 2015 – 16, the BEng and BSc students who completed Semester 2 of the MSP5001 module were asked to provide their opinion / feedback regarding the ARP; this feedback is related to RQ 2 (see chapter 1). The teacher (author) asked the learners to provide their feedback outlining the positive and negative points regarding the teaching, delivery and feedback method of the ARP. An up to 5-minute talk between the teacher and each learner took place, where the teacher wrote down the positive and negative points that each student mentioned.

Most of the students agreed that they preferred the portfolio of exercises as an assessment method; specifically, the students preferred that the workload was evenly distributed during the whole of the semester, as compared to a bigger assignment which the students would have to submit towards the end of the semester. Moreover, in the positives, the students mentioned, amongst others, the following: “(It was important that we used) real data”, “(The output of each portfolio exercise is) something you can see”, “(The module is) interesting in terms of content”, “Excellent Teaching & Learning process”, “Useful feedback”, “(The module) applies in industry”, one learner claimed that he “Learnt more due to the ‘test’ environment”, “Beneficial learning approach. A bit on the (white)board and then hands-on”. The following positive comments were also gathered from the students: “(The module) was well prepared”, “(I was) most confident in this module”, “Favourite module”, “Rewarding module”, “(I would) recommend (this module) to continue in the same way”. Moreover, some students claimed that they: “Learnt MATLAB more” and “Familiarised with MATLAB”.

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The learners have also mentioned a few points of concern in relation to the delivery method of the ARP. Specifically, they said that: "(It would be better to have a) smoother transition to the new way of assessing", "Start with a (portfolio) exercise with lower weighting", "(I would prefer to be provided) with more examples of relevant exercises and with a better background in MATLAB", "(I would prefer) a slower delivery pace", "(I would prefer the teacher to) solve / provide beforehand a similar example with the portfolio exercise", "(I would like to be provided) with a bit more introductory material in relation to the topic", "(I have to wait for) a long time before an answer is given due to the number of students in the classroom", "What happens if a student loses a lecture?"

4.6 Summary

In this chapter, the experiments performed utilising the correlation coefficient aim to identify potential relations between the learners’ academic performance in the Year 1 Mathematics and Science modules with their academic performance in the Year 2 Chassis Development and Telemetry ARP. The results indicate that the learners’ performance in Telemetry, an applications’ Year 2 module, is related to Mathematics and Science Year 1 modules which aim to introduce the students to the basic principles of science and to gain the analytical and software skills required for the engineering course they pursue.

Utilising the k-means algorithm, 13 out of the 14 BEng & BSc students were accurately clustered into two groups. One group corresponds to the BEng students and the other to the BSc students (one misclustered case). This indicates the different profile of the BEng and BSc learners based on their academic performance in Mathematics, Science and the MSP5001 ARP.

The satisfaction of the learners in relation to the MSP5001 module has been reflected through the students’ responses in the MEQs. The level of satisfaction was quantified through the Wilcoxon rank sum algorithm where the students’ responses for the MSP5001 module were compared with the responses regarding the other modules delivered by the School and by the University.

Furthermore, the informal feedback provided to the author by the learners regarding the MSP5001 ARP was positive highlighting its delivery method, the hands-on
approach adopted and the motorsport content of the portfolio exercises. However, some students expressed their concerns probably because they found the transition towards critical thinking and active learning, which the portfolio exercises required, challenging.

More observations in relation to the results presented here are provided in the Discussion chapter.
CHAPTER 5 – Discussion on the significance and implications of research findings

5.1 Introduction

In this chapter, there will be a discussion on certain aspects of the transition process of NCME’s students from passive to active learning and critical thinking, through investigation and analysis of quantitative data derived mainly from an Action Research Project (ARP) which was implemented for the second-year ‘Chassis Development and Telemetry (MSP5001)’ module during Semester 2 of the academic year 2015 – 2016.

The author’s findings that were presented in the previous chapter in relation to the teaching, learning and delivery strategy and methods of this ARP are critically discussed and analysed. The discussion includes:

- Exploration of the potential correlation between the academic performance of the students in the Mathematics, Science and Programming related first year modules (MSP4001 and MSP4005 for the BSc course, and MSP4006 and MSP4007 for the BEng course) with the MSP5001 module, which is a module common to second year BEng and BSc students. This analysis is related with RQ 1 (outlined in chapter 1).

- Discussion on the students’ acceptance of the Project-Based Learning (PJL) as well as Problem-Based Learning (PBL) teaching and learning approach.

- Investigation of the effectiveness of the teaching & learning and delivery methods of the MSP5001 module in comparison with other modules of the School of Engineering and the University of Bolton, in general.

- A critical review of the learners’ feedback as well as the author’s self-reflection in relation to the MSP5001 ARP. The last three points are related with RQ 2 (outlined in chapter 1).

5.2 The utilisation of the Correlation coefficient and the k-means algorithm as tools for learner academic profiles' identification

Regarding RQ 1, which explores the potential correlation between the learners’ prior knowledge and their performance in the ARP of the MSP5001 module, the
The interconnection between certain Year 1 modules and the Year 2 MSP5001 module is demonstrated through their strongly related Learning Outcomes. Since the Learning Outcomes are strongly interconnected, one could expect that a correlation exists between the academic performance of the learners in the Year 1 selected modules and their performance in the Year 2 MSP5001 ARP.

The first-year modules covering the Science and Programming-related curriculum material for the BEng and BSc students are the ‘Performance Engineering Sciences (MSP4006)’ module for the BEng course, and the ‘Chassis and Electronic Principles (MSP4001)’ module for the BSc course, respectively. Certain Learning Outcomes (LOs) of the aforementioned modules are related to the second year ‘Chassis Development and Telemetry (MSP5001)’ module, to include the following:

i) for the MSP4006 module:

“Identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques”.

ii) for the MSP4001 module:

1. “Identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques”, and
2. “Apply mathematical and computer-based models to solve engineering problems”.

The first-year modules covering the Mathematics syllabus for the BEng and BSc students are the ‘Engineering Mathematics (MSP4007)’ module for the BEng course and the ‘Applied Analytical Methods (MSP4005)’ module for the BSc course, respectively. The Learning Outcomes of these modules which relate to the second-year ‘Chassis Development and Telemetry (MSP5001)’ module are:

i) for the MSP4007 module:

1. “Identify, classify and describe the performance of systems and components through the use of analytical methods and modelling techniques”.
2. “Apply quantitative methods and computer software relevant to mechanical and related engineering disciplines, to solve engineering problems”.

ii) for the MSP4005 module:

1. “Demonstrate a comprehensive knowledge and understanding of mathematical and computer models necessary to support application of key engineering principles”,

- 48 -
2. “Monitor, interpret and apply the results of **analysis and modelling** in order to bring about continuous improvement” and

3. “**Apply quantitative methods and computer software** relevant to their engineering technology discipline(s), frequently within a multidisciplinary context”.

As described in chapter 1, all the aforementioned expected Learning Outcomes (LOs) are in line with the IMechE requirements for course accreditation. The full list of Learning Outcomes for MSP4001, MSP4005, MSP4006, MSP4007 and MSP5001 modules can be found at the University of Bolton Module Database (See Appendix, section IV).

It is important to mention that the first-year Mathematics (MSP4005) module of the BSc course is less analytical compared to the equivalent Mathematics’ module (MSP4007) of the BEng course. On the other hand, the BEng and BSc first-year Science and Programming related modules (MSP4001 for the BSc students and MSP4006 for the BEng students) are similar in terms of analytical requirements, although each of them has its content adapted to the scope of the corresponding course. Nevertheless, the second-year ‘Chassis Development and Telemetry (MSP5001)’ module, which is common for both the BEng and the BSc courses, has to be adjusted for both the BEng as well as the BSc learners.

It can be observed that some of the LOs are common among these first-year modules. The common theme in the LOs of these modules is the utilisation of analytical / mathematical / quantitative methods, modelling techniques and computer-based models / software for the application of key engineering principles and for the solution of engineering problems. The first-year modules used in this dissertation have been selected because their LOs are in line with the learning objectives of the MSP5001 second year-module; in this module, the learner has to utilise his/her analytical skills through MATLAB software in order to visualise, analyse, combine and process signals extracted from racing car sensors for making useful observations and drawing conclusions in relation to motorsport applications.

Tables 1 and 2 from chapter 4 present the correlation coefficient between the marks that the students were awarded for the second-year ‘Chassis Development and Telemetry’ ARP and the marks that the BEng and BSc learners were awarded for the Mathematics and Science first-year modules and their average, respectively (i.e., the average mark of the Mathematics and Science modules; see also chapter
The abovementioned results indicate that there is a very strong \(0.8 < r \leq 1\) relationship at the \(\alpha = 0.05\) Level of Significance between the students’ performance in the first year Science module (MSP4001) with the second year Telemetry module (MSP5001) as well as between the average performance, i.e. the average mark of the first year Science module (MSP4001) and Mathematics (MSP4005) module with the second year Telemetry (MSP5001) module for the BSc course.

However, the same observation does not hold for the BEng students; specifically, no strong correlation is observed between the first year Mathematics (MSP4007) and Science (MSP4006) modules with the second year Telemetry module (MSP5001) for the BEng course. In other words, while the academic performance of the BSc students regarding the Year 1 Mathematics and Science modules is positively correlated with their academic performance regarding the Year 2 Telemetry module, the same does not hold for the BEng students.

The aforementioned difference between the students of the BEng and the BSc courses may have to do with the mixed academic background of the learners who attended the BEng course compared to the learners of the BSc course. The profile of the six BEng students was quite diverse compared to the profile of their BSc colleagues. Specifically, two of the BEng learners have completed A-levels in Mathematics (or equivalent), one of them is a mature student with overseas teaching experience and the remaining students have a BTEC background. The eight BSc learners, though, have a less diverse background; specifically, seven of them have a BTEC or Foundation course background and one of them has completed an International Baccalaureate (IB) course.

Thus, students with similar academic backgrounds seem to follow a similar pattern when comparing their academic performance in the Year 1 Mathematics and Science modules to the Year 2 Telemetry module.

The observation that the BEng and the BSc groups of learners form two distinctive groups, based on their academic performance regarding: (i) the module marks for the BSc learners (MSP4001, MSP4005 and MSP5001 modules) and the (ii) module marks for the BEng learners (MSP4006, MSP4007 and MSP5001 modules), is identified through the ‘k-means algorithm’. This is an unsupervised learning algorithm utilised for data clustering (Webb, 2001). Thus, as reported in the first column of Table 4 in chapter 4, the k-means algorithm clustered correctly all
fourteen but one of the BEng and BSc group of NCME students; the single misclassification was one BSc student who was classified as BEng.

Thus, through the correlation coefficient it is identified that, unlike the BEng students, the BSc students follow a similar pattern in terms of their academic performance based on the marks they achieved in certain Year 1 and Year 2 modules. Moreover, based on the marks that the students achieved in certain Year 1 and Year 2 modules, the k-means algorithm identified correctly the two distinctive groups of learners corresponding to the two courses delivered, namely the BEng and the BSc course.

Furthermore, focusing on the marks that the BSc learners achieved in: (i) Mathematics (module MSP4005, Year 1), (ii) Science & Software Programming (module MSP4001, Year 1) and (iii) the ‘Chassis Development and Telemetry’ ARP (module MSP5001, Year 2), the k-means algorithm identified correctly the learners who passed and the learners who failed the MSP5001 module. Specifically, one cluster corresponds to the two students who failed the MSP5001 ARP, whereas the other cluster corresponds to the six students who achieved a mark which is higher than 40% in the ARP (see Figures 6 to 9 of chapter 4).

5.3 The Wilcoxon rank sum test results as an indicator of the effectiveness of the ARP

The results of the ‘Wilcoxon rank sum test’ portrayed a shift of the median value with regards to the responses for certain questions included in the Module Evaluation Questionnaires (MEQs) that were filled in by the students; specifically, a positive shift of the median value was observed towards the ‘Strongly Agree’ end of the spectrum for the learners who attended the MSP5001 module as compared to other learners attending modules at the School of Engineering and the University. The results were obtained through a right-tailed Wilcoxon rank sum test at the $\alpha = 0.025$ level of significance. Regarding the comparison between the MSP5001 module with the modules delivered by the School of Engineering, the aforementioned shift (rejection of Null Hypothesis) was observed with respect to the responses regarding the following MEQ questions:

Question 3: ‘The module content met my expectations’
Question 6: ‘I was encouraged to actively participate during the module’
Question 7: ‘The learning materials used in the module were good’
Question 10: ‘The teaching room(s) used was (were) good’
Question 11: ‘The workload associated with the assignments/coursework was manageable’
Question 12: ‘The assignments (and any exams) were relevant’
Question 13: ‘I received grades and feedback on my assignments within the published timescale’
Question 14: ‘The feedback I have received on my progress has been helpful’
Question 15: ‘The tutor(s) was (were) helpful’
Question 16: ‘Overall, I was satisfied with this module’

Regarding the comparison between the MSP5001 module with the modules delivered by the University, the shift (rejection of Null Hypothesis) was observed with respect to the same responses as in the previous case except of Questions 6 and 7.

A full list of the Questions included in the Module Evaluation Questionnaires (MEQs) of the University of Bolton is available at The University of Bolton (2015).

The answers to the questions where this positive shift was observed could be grouped into three categories, as follows:

(i) Responses to Questions 3, 7 and 12. This first group of responses focuses on the module content, the learning material and the relevancy of the assignments regarding the MSP5001 module. All portfolio exercises utilised for this module were focused on processing sensor signals of racing cars. The learners found the content and the learning material interesting since they could relate it with real-case scenarios. Moreover, the learners were motivated since similar signal processing methods are followed in the racing industry, thus, the students developed their employability skills. Note that for the development of the portfolio exercises, the tutor had consulted a colleague who has twenty years of industrial experience in the field of Data Acquisition for racing cars.

(ii) Responses to Questions 6, 11 and 15. The second category of questions is related to the module delivery approach that the tutor adopted. The students were encouraged to collaborate with their colleagues and to conduct their own research in relation to the portfolio exercises within strict deadlines. Similar conditions apply in the working environment of the motorsport industry. Moreover, the exercises were of increasing difficulty so as to maintain the motivation and interest of the learners during the ARP.
(iii) **Responses to Questions 13 and 14.** The learners were provided with feedback by the tutor within tight timescales in order to be able to rectify their weak points in their following submission. For each exercise, feedback was provided initially to the class as a whole in order to point out common mistakes, and afterwards, individual feedback was provided to each learner. The students stated that brief and frequent feedback was helpful in understanding the learning material.

It is important though to clarify that some of the aspects, such as the ones expressed through Questions 6, 10, 11, 13, 15 and 16, are not directly related to the new learning resources. Specifically, the learners’ active participation, the timely assessment provided by the tutor are more related to the professionalism of the individual rather than to the learning resources. However, the aspects expressed through Questions 3, 7, 11, 12 and 14 are related to the new learning resources. Specifically, the positive attitude of the learners towards the module content and the learning material, the manageable workload, the relevancy of the assignments and the helpful and targeted feedback are related to the portfolio exercises of the ARP.

As mentioned before, the new learning resources contributed to the positive attitude of the learners because the portfolio exercises connected theory with practice and adopted a hands-on approach through the processing of authentic racecar signals. Moreover, the workload was more manageable, because the portfolio exercises of the ARP formed smaller pieces of deliverables compared to a single assignment towards the end of the academic year. The process of delivering small-scale exercises dictated the feedback strategy followed; the feedback strategy followed was effective because the learners and the tutor engaged in dialogue, they elaborated on the learner’s errors each time, feedback was delivered in a timely manner and aimed towards further improvement in learning (Thurlings et al, 2013). Moreover, the feedback enabled the learners clarify concepts, build confidence and the required skills for the following exercises.

Furthermore, as mentioned in section 4.5, the students highlighted the fact that ‘real data’ is utilised for the exercises and that ‘the output of each portfolio exercise is something you can see’, thus, underlying the importance of using ‘authentic’ tasks which are more meaningful for the learners (Schunk, 2011). The positive attitude of the learners is also reflected by the high Pass rates as well as the high Attendance rates as will be presented in section 5.4.
5.4 A comparison between attainment at the ARP and the University / School of Engineering modules as an indicator of the effectiveness of the MSP5001 ARP

In Table 6, a number of statistical values regarding the ARP for the MSP5001 module are presented and compared with the corresponding statistics of the University modules. The MSP5001 ARP statistical values have been calculated by the author based on the students’ performance indicators and are focusing on the ARP which was delivered during Semester 2 of academic year 2015-16, whereas, the University statistics had been provided by the Department of Student Data Management.

From these statistical values, one can observe that the total percentage of the ‘Withdrawn’ and ‘Failed’ rates for the MSP5001 module (0% + 14% = 14%) are lower compared to the corresponding University’s values (8% + 11% = 19%) and that the ‘Pass Rate’ of the MSP5001 (86%) is higher compared to the University’s (76%). Moreover, the Mean mark that the students reached for the MSP5001 ARP portfolio exercises (61%) is higher compared to the University modules’ mean mark value (53%), whereas, the Standard Deviation regarding the ARP portfolio exercises marks is lower (University of Surrey, 2018; Wood, 2015).

The lower standard deviation value of the MSP5001 module marks compared to the standard deviation of the University’s marks shows that the learners’ marks for MSP5001 are less spread compared to the University’s. This metric indicates that despite the diverse academic background of the learners (BEng and BSc mixed group) who participated in the MSP5001 ARP, the delivery method that was followed addressed this challenge by adopting a delivery strategy which facilitated inclusivity.

<table>
<thead>
<tr>
<th></th>
<th>Withdrawn (%)</th>
<th>Failed (%)</th>
<th>Pass Rate (%)</th>
<th>Mean (%)</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSP5001 ARP (Semester 2)</td>
<td>0</td>
<td>14</td>
<td>86</td>
<td>61</td>
<td>28.7</td>
</tr>
<tr>
<td>University modules (average values)</td>
<td>8</td>
<td>11</td>
<td>76</td>
<td>53</td>
<td>38.2</td>
</tr>
</tbody>
</table>

*Table 6: MSP5001 ARP and University statistics*
Another indicator regarding the effectiveness of the ARP is that the attendance rate during Semester 2 for module MSP5001 was 87%, whereas, the average attendance across the School of Engineering during both Semesters regarding academic year 2015-16 was 70%. The attendance rates were retrieved through the University’s database and provided by the Head of School of Engineering. (Note that it was not feasible to find the attendance rate across the School only for Semester 2).

5.5 Transition towards Active Learning and Critical Thinking

In section 4.5 of the Results chapter (chapter 4), the informal feedback provided by the students regarding the MSP5001 ARP was reported. The feedback focused on the positive and negative aspects which the learners identified in relation to the new delivery approach introduced by the ARP for the ‘Chassis Development and Telemetry’ module. Most of the students were satisfied with the newly adopted teaching, learning and assessment approach. Specifically, they mentioned that they preferred to submit a group of portfolio exercises which have a common theme and spread across the Semester compared to the more traditional ‘single assignment’ method (in this case, the theme was related to the analysis and processing of signals extracted from sensors installed in a racing car).

Along similar lines, the learners appreciated the regular brief feedback which was provided to them by the tutor (on average, feedback was provided for every two portfolio exercises) rather than providing analytic feedback once per Semester. The students also highlighted the importance of processing and analysing ‘real’ rather than synthetic signals, hence, relating directly the theory with practice. Moreover, the delivery pattern was appreciated by the students; theory and brief examples were presented on the whiteboard by the teacher and then followed the hands-on practise via the portfolio exercise. Some students also claimed that their knowledge and understanding with regards to MATLAB software was improved via the portfolio exercises.

Nevertheless, some students expressed their concerns in relation to the ‘rapid’ transition towards this new delivery method. They would have preferred more exercises, similar to the ones that they were assessed on, to be solved by the tutor.
as well as more lectures on MATLAB in order to further familiarise themselves with the software. Similar observations were reported in (Hoffbeck et al., 2016); see section 2.6 of chapter 2.

The positive learners’ comments indicate their gradual transition from being passive to becoming active learners. During the course of their studies, most of the students become academically mature thus, take ownership of their learning and start developing their own knowledge. In this transition the role of the tutor is to facilitate, rather than to direct, the learning process, and consequently to promote critical thinking as well as independent and active learning.

The portfolio exercises of the ARP promote active learning and critical thinking. The teacher acts as a coach who delivers theory which is then put into practice. The exercises are purposive, realistic and engaging since they are related to real-case scenarios in motorsports thus, enhancing the employability skills of the learners. The exercises are also reflective because the students apply the knowledge acquired from the Mathematics and Science Year 1 modules to the Chassis Development and Telemetry Year 2 module (Kyriacou, 1992). Moreover, the ARP promotes interdisciplinary learning since it requires the combination of analytical and software (programming) skills with Motorsports (Grabinger and Dunlap, 1995). Furthermore, the portfolio exercises require the interpretation and utilisation of the information conveyed by the sensor signals in order to draw observations and conclusions in relation to Motorsport applications (Laurie Santos, 2017; Duchscher, 1999).

However, it is a challenge for the teacher that all learners do not experience this transition phase towards active learning and critical thinking at the same time with certain students preferring to continue learning via the more traditional method where the teacher directs the learning process.

5.6 The Tutor’s perspective / A brief self-reflection

The ‘Chassis Development and Telemetry’ is a second-year module which requires knowledge and understanding of the importance of sensors in Motorsports. It comprises a hardware part, e.g., types of sensors, how to install and calibrate a sensor in a racing car etc. as well as a software part, e.g., how to interpret, process
and analyse the signal of a sensor. The portfolio exercises delivered during Semester 2 as part of this ARP focused only on the software part. However, it needs to be highlighted that a competent graduate motorsport engineer needs to have the ability to work under pressure within limited time and to have a solid background in both the hardware and the software parts of racecar Data Acquisition Systems.

The ‘Chassis Development and Telemetry’ module is a challenging module, in terms of its delivery, for teachers who have a ‘traditional’ academic background since this module incorporates a strong hands-on element. Moreover, the academic resources available for Motorsport courses in Higher Education are limited, since few good academic journals and textbooks in the field of Motorsport Engineering, in general, as well as in the field of Racecar Data Acquisition in particular, are available.

Ideally, this module should be developed and delivered following input from industry experts with experience in the field of data acquisition from racecar sensors and, equally important, with relevant academic qualifications (e.g., a Bachelor degree in Engineering or a related discipline) in order to understand the Higher Education framework and environment. The industrial experience of the motorsport experts should be recent, because the sensor technology of racecars has been significantly evolving during the last few years both in terms of hardware as well as software.

For that reason, during academic year 2015-16, the MSP5001 module was shared between the author and a colleague who is a graduate engineer and has been working in the motorsport industry for over 20 years. The author worked closely with the data acquisition expert who offered valuable insight in order to develop the portfolio exercises and also played a key role as a ‘critical friend’ in relation to the ARP’s scope. The nature of these exercises and the time constraints regarding the submission deadlines aimed to reflect the challenges which a Data Acquisition motorsport engineer faces, so that the learners could develop the required knowledge and skills and fulfil the module’s Learning Outcomes. In other words, the aim of this ARP was to ‘simulate’ the racecar data acquisition engineer’s professional environment within the HE framework.

The hardware part of this module was delivered by the author’s colleague (industry expert), whereas the software was delivered by the author. Regarding the software part, the learners were required to visualise, analyse and process data in order to
be able to extract features, make observations and draw reliable conclusions from the sensor / processed sensor signals; in other words, the learners were required to translate data into useful information utilising software. An important parameter of the portfolio exercises is that the students should be able to develop their own software code in order to visualise, process and analyse the motorsport signals since the utilisation of existing commercial software packages for the aforementioned tasks is not adequate for the requirements of a Higher Education Engineering module. The portfolio exercises developed for the ARP were short, yet challenging, with strong motorsport content and at the same time they were covering the Learning Outcomes of this Level 5 module. Feedback for each portfolio exercise was provided by the author to the students within (maximum) two weeks’ time after their submission.

Although the analysis indicated a positive impact in relation to the teaching & learning and delivery method of the MSP5001 module, one of the main concerns of the author is whether the same delivery approach could be adopted for classes with a higher number of students, for instance, more than 25 learners. Thus, one of the main challenges which a teacher might have to face for the case of bigger classes has to do with the amount of marking required in relation to the number of portfolio exercises submitted during the semester, as well as the requirement for giving rapid feedback to the learners.

Furthermore, for portfolio-oriented module delivery, as in the case of the ARP examined in this dissertation, there should be a minimum requirement for learners’ attendance rates. Students who have not been able to attend the theory related to the corresponding portfolio exercise might not be able to submit their work. Consequently, since the theory delivered is closely related to the portfolio exercises, the teacher may have to repeat selected lectures so as to give the opportunity to absentees to prepare and submit outstanding portfolio work. In any case, attendance rate limitations should be imposed to the students, otherwise it may not be possible for all learners to submit and be assessed on the same number of portfolio exercises.
5.7 Summary

In this chapter, the Results previously presented in chapter 4 are discussed. Specifically, the correlation identified between the BSc learners’ academic performance regarding the Year 1 Mathematics and Science modules with the Year 2 MSP5001 ARP was justified. Moreover, the BSc and BEng groups of learners identified using the k-means clustering algorithm based on the students’ academic performance regarding the Year 1 Mathematics and Science modules and the Year 2 MSP5001 ARP, were presented. The results obtained through the Wilcoxon rank sum test, which was utilised in order to examine the overall efficiency of the proposed MSP5001 ARP compared to the other modules delivered by the School of Engineering and the University through the students’ responses in the MEQs, were also discussed. Other measured quantities such as the Pass and Attendance rates were also used in order to support the observations and discussion. A brief analysis from the learners' perspective as well as the author's self-reflection in relation to this ARP have also been incorporated.
CHAPTER 6 – Summary, Conclusions and Future Plans

Summary

Today's Engineering and Technology graduates not only need to have in-depth knowledge of their subject, but also need to be equipped with a wide range of skills that will be useful in terms of their employability. During the first year of an undergraduate engineering course, the modules usually cover teaching material related to the analytical and scientific foundation the learners need to develop, whereas during years 2 and 3 the curriculum aims towards the development of the learners' knowledge through applications in their corresponding engineering field. In other words, in Year 2 commences the transition of the students towards active learning and critical thinking.

This study is focused on the transition of learners of HE Motorsport courses towards becoming active learners and critical thinkers through the utilisation of project and problem-based learning. Specifically, it focuses on the delivery of the ‘Chassis Development and Telemetry (MSP5001)’ module, a second-year module common to the ‘BEng in Automotive Performance Engineering’ and the ‘BSc in Motorsport Technology’ courses at the National Centre for Motorsport Engineering (NCME) of the University of Bolton.

The MSP5001 module was selected for this research because it is a hands-on module where the learners are expected to acquire knowledge and develop skills which are required for the profession of Data Acquisition Engineer in Motorsports; consequently, this module is appropriate for applying Project and Problem - based learning methods, whilst taking into consideration that both NCME courses have been accredited by the Institution of Mechanical Engineers (IMechE), and that their Learning Outcomes are aligned with the requirements of the professional body.

During academic year 2015-16, which was the second time the MSP5001 module ran, the author developed an Action Research Project in order to facilitate Project and Problem - based learning through a series of short portfolio exercises focusing on the analysis and processing of motorsport signals acquired from motorsport sensors; MATLAB software was used for the analysis and processing of these signals. The portfolio exercises had tight submission deadlines and involved the utilisation of ‘authentic’ signals, which were extracted from racecar sensors. Thus,
the ARP aimed to simulate the profession of the Motorsport Data Acquisition Engineer within the HE framework.

This study was organised into two Research Questions. The first Research Question investigates whether the students’ academic performance in the Year 1 modules, which covered mathematics, science and MATLAB programming principles, was related with their academic performance in the Year 2 MSP5001 ARP, where these principles were utilised. The data used for this Research Question included the students’ marks in the relevant modules, and the quantitative tools utilised were the Pearson Product-moment Correlation Coefficient (r) and the k-means algorithm.

The second Research Question explored whether the implementation of the MSP5001 ARP improved the learning experience of motorsport students as compared with the learning experience gained by students attending other modules within the School of Engineering or the University. The data for this Research Question utilised the learners’ responses at the University’s Module Evaluation Questionnaires (MEQs), the learners’ attendance and pass rates for the MSP5001 module, while quantitative tools included the Wilcoxon rank sum test and basic statistical analysis. Moreover, for the second Research Question, the students’ feedback, which was provided via short interviews to the author (module tutor), as well as the author’s self-reflection were utilised.

Conclusions & Recommendations

The main conclusions and observations stemming from this research were thoroughly presented in the Discussion chapter and may be summarised as follows:

Regarding Research Question 1, the experimental results indicated that a relation existed between the learners’ academic performance in the selected Year 1 modules and their performance in the Year 2 MSP5001 ARP, however, only for the BSc and not for the BEng learners. The quantitative analysis also indicated that there were differences between the BEng and the BSc learners’ academic backgrounds. Due to the diverse prior-knowledge background of the BEng and the BSc students, it could be suggested that the MSP5001 module should be organised into two different classes, one for the BEng and one for the BSc learners. This
recommendation has already been effectuated from the beginning of academic year 2017-18.

Regarding Research Question 2, the experimental results indicated that the learners were more satisfied by many aspects of the teaching and learning method adopted as part of the MSP5001 ARP as compared to the satisfaction levels experienced through the delivery of other modules offered either by the School of Engineering or the University; the results were also supported by the informal feedback provided to the author by the learners.

The observations, as presented in the Discussion chapter, pointed out that project and problem-based learning was well-received by the learners of the motorsport courses. Specifically, the responses of the learners regarding the incorporation of real-case scenarios, as part of the second-year MSP5001 ARP, were very encouraging and indicated that the curriculum of engineering modules in HE should incorporate hands-on industrial input, where possible. Features such as the application of analytical and scientific principles, the utilisation of software for real-case problems involving signals acquired from racecars and the tight submission deadlines promoted active learning and critical thinking; the learners needed to consider a wide range of practical and theoretical parameters such as the utilisation of data for information extraction and decision making, time management etc.

It is important to mention that the learners’ responses to the Module Evaluation Questionnaire for academic year 2016-17 (i.e., the following academic year of this ARP’s launch), where similar portfolio exercises were utilised, were very positive; see the corresponding Module Evaluation Questionnaire Polarity Responses for the ‘Chassis Development and Telemetry’ module in Appendix, section VI (number of respondents: twelve). Along similar lines, the informal feedback of the learners during Semester 1 of academic year 2017-18 regarding the MSP5001 module was very encouraging as well.

Despite the encouraging quantitative research results and feedback in relation to the MSP5001 ARP, it is important to highlight the weak points of this research as well as to propose potential future steps for further research.
Weaknesses of the Research

Probably the most important weakness of this ARP is the small number of participants, due to the small number of students who enrolled in the MSP5001 module. Specifically, the total number of students who were enrolled in the module during academic year 2015-16 was fourteen. Consequently, due to the small sample number, the observations and conclusions of this work regarding both Research Questions cannot be generalised.

Furthermore, focusing on the observations of Research Question 2, one could argue that the positive feedback of the learners regarding the ARP can be attributed to the students’ maturation during the second year of their studies rather than to the quality of the ARP per se.

For the same Research Question, in the experiments conducted utilising the Module Evaluation Questionnaires (chapter 4), the ‘Strongly Disagree’, ‘Disagree’, ‘Agree’ and ‘Strongly Agree’ responses were quantified as 1, 2, 3 and 4, respectively. However, this linear scaling is not necessarily the correct approach and a non-linear scale could be adopted instead.

Finally, it is important to note that the same ARP could be difficult to be applied to classes consisting of a high number of learners due to the potentially heavy workload for the teacher in terms of marking the portfolio exercises, providing feedback to the learners as well as to follow-up with the learners who did not attend the sessions when the portfolio exercises were delivered.

Future Plans

Closing this work, a few ideas about futures plans related to this ARP may be summarised as follows. With regards to the problems occurring when the learners fail to attend certain classes, the lectures could be video-recorded so that the absentees could follow-up with the theory covered in relation to a portfolio exercise.

Moreover, an enriched version of this ARP could be delivered during the subsequent academic years and investigate whether similar conclusions and observations would be drawn. Ideally, the number of students (sample) participating in the ARP would be higher so that the conclusions and observations would be more reliable.
Similar ARPs, incorporating strong elements of Project and Problem-Based Learning, could be designed and delivered within other Year 2 and Year 3 engineering modules. More importantly, these future ARPs would involve input from more industry experts and their impact could be measured in relation to the students’ employment status after the completion of their studies.
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APPENDIX

I. Consent Form

02 November 2016

Title of Project (provisional): “The role of mathematical-related software as a tool for the transition towards active learning and critical thinking”

Researcher:

Dr. Ioannis Paraskevas (CEng, CMath, FHEA)
School of Engineering
University of Bolton
Deane Road, Bolton
Greater Manchester
BL3 5AB

1. I have had the opportunity to consider the information, ask questions regarding the project and have had these questions answered satisfactorily.

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

3. I understand that any information which has been or will be provided by me may be used in a dissertation, future reports, articles or presentations by the researcher.

Please note that information which could be utilised for this research includes, but is not limited to, Mathematics’ Diagnostic Test results, ‘Motivated Strategies for Learning Questionnaire’ responses, ‘Matlab software as a tool for Teaching & Learning and Employability Skill Questionnaire’ responses as well as Examination results, Assignment results, Attendance Records, Responses of Module Evaluation Questionnaires, Formal and Informal feedback provided by the student regarding the modules: Applied Analytical Methods (MSP4005), Chassis and Electronic Principles (MSP4001), Engineering Mathematics (MSP4007), Performance Engineering Sciences (MSP4006), Chassis Development and Telemetry (MSP5001), Engineering Modeling and Analysis (MSP5007), Vehicle Dynamics and Advanced Electronics (MSP6001).

4. I understand that my name will not appear in any reports, articles or presentations.

5. I agree to take part in the aforementioned project.
II. Information Sheet - Consent Form

02 November 2016

I would like to ask the third year undergraduate students of CAPE to participate in the Action Research Project (APR) entitled: The role of mathematical-related software as a tool for the transition towards active learning and critical thinking

The theme of this ARP is focusing on the role of mathematical-related software as an assistive teaching and learning tool for the application of mathematical/analytical and science principles to engineering applications or, in other words, the role of software in the contemporary engineering curriculum for the transition of students from passive towards active learners and critical thinkers. This ARP is related to my previous work focused on the ‘Compensatory learning in Mathematics through additional supportive teaching for Motorsport Technology students with vocational-oriented knowledge background’ and ‘Matlab computer software as a tool for Teaching & Learning and as an Employability skill for Engineering Courses’. These works had been focusing on the teaching and learning of mathematics as well as the importance of mathematical-related software for engineering courses in Higher Education; the data for the aforementioned projects had been collected with the consent of the first and second year students who have now reached the final year of their undergraduate studies.

Thus, I would like to ask the learners who have participated in the two previous works to provide me with their consent to utilise the data which I collected in the past in order to be processed from a different perspective. Furthermore, I would like to ask the students to participate in interviews and to respond to Questionnaires which I may develop as part of this work.

Specifically, the acquired information which could be utilised for this ARP includes, but is not limited to, Mathematics’ Diagnostic Test results, ‘Motivated Strategies for Learning Questionnaire’ responses, ‘Matlab software as a tool for Teaching & Learning and Employability Skill Questionnaire’ responses as well as Examination results, Assignment results, Attendance Records, Responses of Module Evaluation Questionnaires, Formal and Informal feedback provided by the student regarding the modules: Applied Analytical Methods (MSP4005), Chassis and Electronic Principles (MSP4001), Engineering Mathematics (MSP4007), Performance Engineering Sciences (MSP4006), Chassis Development and Telemetry (MSP5001), Engineering Modeling and Analysis (MSP5007), Vehicle Dynamics and Advanced Electronics (MSP6001).

If you have any questions regarding this ARP please do not hesitate to ask me.

If you are in agreement with the Terms and Conditions with regards to your participation in this ARP please sign the attached Consent Form.

Kind regards,
Ioannis Paraskevas
APPROVED BY THE UNIVERSITY OF BOLTON RESEARCH ETHICS COMMITTEE
III. Research Ethics Checklist
Form RE1

This checklist should be completed for every research project which involves human participants. It is used to identify whether a full application for ethics approval needs to be submitted.

Before completing this form, please refer to the University Code of Practice on Ethical Standards for Research Involving Human Participants. The principal investigator and, where the principal investigator is a student, the supervisor, is responsible for exercising appropriate professional judgment in this review.

This checklist must be completed before potential participants are approached to take part in any research.

Section I: Applicant Details

<table>
<thead>
<tr>
<th>1. Name of Researcher (applicant):</th>
<th>Ioannis Paraskevas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lecturer at the School of Engineering,</td>
</tr>
<tr>
<td></td>
<td>University of Bolton.</td>
</tr>
<tr>
<td>3. Email Address:</td>
<td><a href="mailto:I.Paraskevas@bolton.ac.uk">I.Paraskevas@bolton.ac.uk</a></td>
</tr>
<tr>
<td>4a. Contact Address:</td>
<td>School of Engineering</td>
</tr>
<tr>
<td></td>
<td>University of Bolton</td>
</tr>
<tr>
<td></td>
<td>Deane Road</td>
</tr>
<tr>
<td></td>
<td>Bolton BL3 5AB</td>
</tr>
<tr>
<td>4b. Telephone Number:</td>
<td>01204 903847</td>
</tr>
</tbody>
</table>

Section II: Project Details

| 5. Project Title: | The role of mathematical-related software as a tool for the transition towards active learning and critical thinking (provisional title). |
### Section III: For Students Only:

<table>
<thead>
<tr>
<th></th>
<th>Course title and module name and number where appropriate</th>
<th>Dissertation EDM7050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>School/Centre:</td>
<td>School of Education &amp; Psychology</td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Supervisor's or module leader's name:</td>
<td>Dr. Daniela Bacova</td>
</tr>
<tr>
<td>8.</td>
<td>Email address:</td>
<td><a href="mailto:d.bacova@bolton.ac.uk">d.bacova@bolton.ac.uk</a></td>
</tr>
<tr>
<td>9.</td>
<td>Telephone extension:</td>
<td>ext 3219</td>
</tr>
</tbody>
</table>

**Declaration by Researcher (Please tick the appropriate boxes)**

- ✓ I have read the University’s Code of Practice
- ✓ The topic merits further research
- ✓ I have the skills to carry out the research
- ✓ The participant information sheet, if needed, is appropriate
- ✓ The procedures for recruitment and obtaining informed consent, if needed, are appropriate
- ✓ The research is exempt from further ethics review according to current University guidelines
- ✓ Where relevant, I have read the ethical guidelines of the regulatory body that is relevant to my discipline and verify that the research adheres to these guidelines
<table>
<thead>
<tr>
<th>Comments from Researcher, and/or from Supervisor if Researcher is Undergraduate or Taught Postgraduate student:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The research will focus on eliciting students' responses to the implementation of new teaching and learning resources. The participants will be informed about the purpose and aims of the study; they will be provided with the participant consent form and reassured that their participation is voluntary and has no impact on their learning or assessment.</td>
</tr>
</tbody>
</table>
Section IV: Research Checklist

Please answer each question by ticking the appropriate box:

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Will the study involve participants who are particularly vulnerable or who may be unable to give informed consent (e.g. children, people with learning disabilities, emotional difficulties, problems with understanding and/or communication, your own students)?</td>
<td>☐</td>
</tr>
<tr>
<td>2.</td>
<td>Will the study require the co-operation of a gatekeeper for initial access to the groups or individuals to be recruited (e.g. students at school, members of self-help group, residents of nursing home)?</td>
<td>☐</td>
</tr>
<tr>
<td>3.</td>
<td>Will deception be necessary, i.e. will participants take part without knowing the true purpose of the study or without their knowledge/consent at the time (e.g. covert observation of people in non-public places)?</td>
<td>☐</td>
</tr>
<tr>
<td>4.</td>
<td>Will the study involve discussion of topics which the participants may find sensitive (e.g. sexual activity, own drug use)?</td>
<td>☐</td>
</tr>
<tr>
<td>5.</td>
<td>Will drugs, placebos or other substances (e.g. food substances, alcohol, nicotine, vitamins) be administered to or ingested by participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind?</td>
<td>☐</td>
</tr>
<tr>
<td>6.</td>
<td>Will blood or tissues samples be obtained from participants?</td>
<td>☐</td>
</tr>
<tr>
<td>7.</td>
<td>Will pain or more than mild discomfort be likely to result from the study?</td>
<td>☐</td>
</tr>
<tr>
<td>8.</td>
<td>Could the study induce psychological stress or anxiety or cause harm or negative consequences beyond the risks encountered in normal life?</td>
<td>☐</td>
</tr>
<tr>
<td>9.</td>
<td>Will the study involve prolonged or repetitive testing?</td>
<td>☐</td>
</tr>
<tr>
<td>10.</td>
<td>Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?</td>
<td>☐</td>
</tr>
<tr>
<td>11.</td>
<td>Will participants’ right to withdraw from the study at any time be withheld or not made explicit?</td>
<td>☐</td>
</tr>
<tr>
<td>12.</td>
<td>Will participants’ anonymity be compromised or their right to anonymity be withheld or information they give be identifiable as theirs?</td>
<td>☐</td>
</tr>
<tr>
<td>13.</td>
<td>Might permission for the study need to be sought from the researcher’s or from participants’ employer?</td>
<td>☐</td>
</tr>
<tr>
<td>14.</td>
<td>Will the study involve recruitment of patients or staff through the NHS?</td>
<td>☐</td>
</tr>
</tbody>
</table>

If ALL items in the Declaration are ticked AND if you have answered NO to ALL questions in Section IV, send the completed and signed Form RE1 to your School/Centre Research Ethics Officer for information. You may proceed with the research but should follow any subsequent guidance or requests from the School/Centre Research Ethics Officer or your supervisor/module leader where
appropriate. Undergraduate and taught postgraduate students should retain a copy of this form and submit it with their research report or dissertation (bound in at the beginning). MPhil/PhD students should submit a copy to the Board of Studies for Research Degrees with their application for Registration (R1). Work which is submitted without the appropriate ethics form will be returned unassessed.

If ANY of the items in the Declaration are not ticked AND / OR if you have answered YES to ANY of the questions in Section IV, you will need to describe more fully in Section V of the form below how you plan to deal with the ethical issues raised by your research. This does not mean that you cannot do the research, only that your proposal will need to be approved by the School/Centre Research Ethics Officer or School/Centre Research Ethics Committee or Sub-committee. When submitting the form as described in the above paragraph you should substitute the original Section V with the version authorized by the School/Centre Research Ethics officer.

If you answered YES to question 14, you will also have to submit an application to the appropriate external health authority ethics committee, after you have received approval from the School/Centre Research Ethics Officer/Committee and, where appropriate, the University Research Ethics Committee.
IV. Module Database

- https://modules.bolton.ac.uk/MSP4001
- https://modules.bolton.ac.uk/MSP4005
- https://modules.bolton.ac.uk/MSP4006
- https://modules.bolton.ac.uk/MSP4007
- https://modules.bolton.ac.uk/MSP5001
V. Quantitative methods – Worked Examples

(i) The Scatterplot and the Pearson Product-moment Coefficient (r)

An example follows on how to develop a Scatterplot and on how to calculate the correlation coefficient, $r_{xy}$, between variables $x$ and $y$ (Table 1A).

<table>
<thead>
<tr>
<th>Data point</th>
<th>Variable $x$</th>
<th>Variable $y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>900</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>2100</td>
<td>230</td>
</tr>
<tr>
<td>3</td>
<td>3000</td>
<td>290</td>
</tr>
<tr>
<td>4</td>
<td>3800</td>
<td>470</td>
</tr>
<tr>
<td>5</td>
<td>5100</td>
<td>590</td>
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<tr>
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<td>6200</td>
<td>610</td>
</tr>
<tr>
<td>7</td>
<td>7300</td>
<td>600</td>
</tr>
<tr>
<td>8</td>
<td>7700</td>
<td>570</td>
</tr>
</tbody>
</table>

*Table 1A: Data points of variables $x$ and $y*

The Scatterplot developed based on the $x$ and $y$ pairs of values (Table 1A) is presented in Figure 1A.

From Figure 1A it can be observed that there is a positive trend; specifically, as variable $x$ increases, variable $y$ increases as well. This trend can be quantified through the Pearson Product-moment Coefficient ($r$).
The steps in order to calculate $r_{xy}$, are as follows:

**Step 1:** Calculate $S_{xx}$ (Equation 2), $S_{yy}$ (Equation 3) and $S_{xy}$ (Equation 4)

In order to calculate the aforementioned quantities, Table 2A has been developed

<table>
<thead>
<tr>
<th>$i$</th>
<th>$x_i$</th>
<th>$y_i$</th>
<th>$x_i^2$</th>
<th>$y_i^2$</th>
<th>$x_iy_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>900</td>
<td>45</td>
<td>810000</td>
<td>2025</td>
<td>40500</td>
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<td>2100</td>
<td>230</td>
<td>4410000</td>
<td>52900</td>
<td>483000</td>
</tr>
<tr>
<td>3</td>
<td>3000</td>
<td>290</td>
<td>9000000</td>
<td>84100</td>
<td>870000</td>
</tr>
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<td>6200</td>
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<td>372100</td>
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<td>7</td>
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<td>360000</td>
<td>4380000</td>
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<td>7700</td>
<td>570</td>
<td>59290000</td>
<td>324900</td>
<td>4389000</td>
</tr>
</tbody>
</table>

| $\sum_{i=1}^{n} x_i$ | 36,100 | $\sum_{i=1}^{n} y_i$ | 3,405 | $\sum_{i=1}^{n} x_i^2$ | 205,690,000 | $\sum_{i=1}^{n} y_i^2$ | 1,765,025 | $\sum_{i=1}^{n} x_iy_i$ | 18,739,500 |

Table 2A: Evaluation of $S_{xx}$, $S_{yy}$, $S_{xy}$

From equations (2), (3) and (4) and using the results from Table 2A:

$$S_{xx} = \sum_{i=1}^{n} x_i^2 - \left(\frac{\sum_{i=1}^{n} x_i}{n}\right)^2 = 205,690,000 - \frac{36,100^2}{8} = 42,788,750$$

$$S_{yy} = \sum_{i=1}^{n} y_i^2 - \left(\frac{\sum_{i=1}^{n} y_i}{n}\right)^2 = 1,765,025 - \frac{3,405^2}{8} = 315,771.875$$

$$S_{xy} = \sum_{i=1}^{n} x_iy_i - \left(\frac{\sum_{i=1}^{n} x_i}{n}\right) \cdot \left(\frac{\sum_{i=1}^{n} y_i}{n}\right) = 18,739,500 - \frac{36,100 \cdot 3,405}{8} = 3,374,437.5$$

**Step 2:** Calculate the correlation coefficient $r_{xy}$
Substituting $S_{xx}$, $S_{yy}$ and $S_{xy}$ into equation (1) we get:

$$r_{xy} = \frac{S_{xy}}{\sqrt{S_{xx} \cdot S_{yy}}} = \frac{3,374,437.5}{\sqrt{42,788,750 \cdot 315,771.875}} = 0.9180$$

Since, $0.8 < r_{xy} < 1.0$ this shows that there is a very strong relationship between variable $x$ and variable $y$ (Molyn, 2012).

**Step 3: Hypothesis Test for the Correlation Coefficient**

In this step, the correlation coefficient obtained in Step 2 is tested in terms of its significance. Specifically, utilising the Hypothesis test it is examined how unlikely is the event that the calculated correlation coefficient value obtained could have occurred by chance. Thus, a t-test is performed where the Null Hypothesis ($H_0$) corresponds to: $r_{xy} = 0$ and the Alternative Hypothesis ($H_A$) corresponds to: $r_{xy} \neq 0$ or in other words $H_A$ corresponds to $r_{xy} > 0$ and $r_{xy} < 0$.

Note that this is a two-tailed test since $H_A$ corresponds to $r_{xy} > 0$ and $r_{xy} < 0$ (non-directional hypothesis) whereas, the one-tailed test is performed in case the alternative hypothesis $H_A$ would correspond to $r_{xy} > 0$ or $r_{xy} < 0$ (directional hypothesis) (University of Washington, 2018; Kenneth, 2017; Penn, 2017b; Stone and Ellis, 2016; Sommer, 2006).

The procedure of statistical Hypothesis testing in relation to the correlation coefficient could be summarised as follows:

i) Calculate the test statistic, $t^*$, via the formula:

$$t^* = \frac{r_{xy}\sqrt{n-2}}{\sqrt{1-r_{xy}^2}} \quad (5)$$

For this exercise: $t^* = \frac{r_{xy}\sqrt{n-2}}{\sqrt{1-r_{xy}^2}} = \frac{0.9180\sqrt{8-2}}{\sqrt{1-0.9180^2}} = 5.67$

ii) Use the ‘Student’s t distribution’ table in order to find the p-value which corresponds to $t^*$. 
Knowing that: the value of $t^*$ is 5.67, the degrees of freedom (df) equal to $n - 2 = 8 - 2 = 6$ and that the test is a two-tailed test then, the p-value can be found via the ‘Student’s t distribution’ table (Athienitis, 2018; Gerstman, 2018) or via software.

Looking at the Student’s t Distribution table it can be seen that for df=6 and $t^* = 5.67$ the p-value or calculated probability has a value between 0.0005 and 0.001 for a one-tailed test or between 0.001 and 0.002 for a two-tailed test. Utilising the software, the exact p-value is found which is 0.0013 for a two-tailed test.

iii) Compare the p-value obtained (p-value=0.0013) with the selected level of significance, $\alpha$; for this case we select the conventional level of significance $\alpha = 0.05$.

Comparing the p-value with the selected level of significance it can be observed that $p\text{-value} < \frac{\alpha}{2} \ (0.0013 < \frac{0.05}{2} \Rightarrow 0.0013 < 0.025)$ thus, the null Hypothesis, $H_0$, can be rejected. Note that in the inequality before, $\frac{\alpha}{2}$ is used instead of $\alpha$ because it is a two-tailed rather than an one-tailed test. Consequently, at the $\alpha = 0.05$ level of significance, it can be concluded that a relationship exists between variables $x$ and $y$ (Mathworks, 2017e; Frost, 2015b).

Note that, the results obtained with hand calculations for this example are verified via the MATLAB software.

The Correlation coefficient is utilised in order to identify potential correlation(s) between the students’ academic performance in selected Year 1 modules with their performance in the MSP5001 ARP.

(ii) The k-means algorithm

The following example describes the steps of the k-means algorithm in order to cluster Data Points into groups based on their location on the Cartesian coordinate system (Table 3A). For this example, we have selected the number of groups where the four data points will be clustered to be two (Group A and Group B) and that the
initial centroids of the two clusters to be the coordinates of Data Point 1 and Data Point 2 (Kardi, 2017).

<table>
<thead>
<tr>
<th></th>
<th>Coordinate x</th>
<th>Coordinate y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Point 1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Data Point 2</td>
<td>2</td>
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<tr>
<td>Data Point 3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Data Point 4</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Data Point 1 (Centroid A) (1,1)</th>
<th>Data Point 2 (Centroid B) (2,1)</th>
<th>Data Point 3 (4,3)</th>
<th>Data Point 4 (5,4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centroid A (1,1)</td>
<td>0.0</td>
<td>1.0</td>
<td>3.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Centroid B (2,1)</td>
<td>1.0</td>
<td>0.0</td>
<td>2.8</td>
<td>4.2</td>
</tr>
</tbody>
</table>

*Table 3A: Cartesian coordinates of Data Points 1, 2, 3 and 4*

Step 1: Initiate the centroids & Select the number of clusters.
It is decided that the four Data Points of Table 3A should be clustered into two groups namely, Group A and Group B and that the initial centroids for Group A and Group B are: A (1,1) and B (2,1), respectively. Note that (1,1) and (2,1) are the x and y coordinates of Data Points 1 and 2, respectively.

Step 2: Calculate the Euclidean distance between each Data Point and each one of the Centroids.
The Euclidean distance, d, between two points with coordinates \((x_1, y_1)\) and \((x_2, y_2)\) is given by the formula: 
\[ d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \]
(Weisstein, 2017).

Thus, the Euclidean distances between each one of the four Data Points and Centroid A and Centroid B are presented in Table 4A.
Step 3: Cluster each Data Point to a Group based on the minimum distance between each Data Point and the initial Centroids.

Data points which are located closer to Centroid A ‘belong’ to Group A and Data points which are located closer to Centroid B ‘belong’ to Group B. Thus, by observing Table 4A it can be seen that Data Point 3 is located closer to Centroid B compared to Centroid A since $2.8 < 3.6$ and similarly, Data Point 4 is located closer to Centroid B compared to Centroid A since $4.2 < 5.0$. Thus, Data Points 1 to 4 can be clustered as in Table 5A.

<table>
<thead>
<tr>
<th>Clustering</th>
<th>Data Point 1</th>
<th>Data Point 2</th>
<th>Data Point 3</th>
<th>Data Point 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td></td>
</tr>
</tbody>
</table>

*Table 5A: Initial clustering of Data Points*

After completing this stage, the ‘updated’ centroid coordinates for Group A and Group B could be obtained by calculating the average value of the x and y coordinates of the Data Points which belong to Group A and to Group B, respectively.

Specifically, the coordinates of the centroid of Group A coincide with the coordinates of Data Point 1 since Group A consists of Data Point 1 only thus, the coordinates of Centroid A remain the same i.e. the coordinates of Centroid A are $(1,1)$. However, since Group B consists of Data Points 2, 3 and 4 then, its updated centroid could be found by calculating the average value of the x coordinates and y coordinates of Data Points 2, 3 and 4.

Thus, utilising Table 3A and Table 5A, the coordinates of Centroid B are:

$$\left(\frac{2+4+5}{3}, \frac{1+3+4}{3}\right) \rightarrow \left(\frac{11}{3}, \frac{8}{3}\right)$$

Step 4: Calculate the Euclidean distance between each Data Point and each one of the updated Centroids – Iteration 1

The same process as in Step 2 is repeated however, now the distance of each Data Point is calculated from the updated centroids obtained in Step 3. The results of these calculations are presented in Table 6A.
### Table 6A: Calculated distances between Data points 1, 2, 3 and 4 and (i) updated Centroid A (row 1) and (ii) updated Centroid B (row 2) – Iteration 1

<table>
<thead>
<tr>
<th></th>
<th>Data Point 1 (Centroid A)</th>
<th>Data Point 2</th>
<th>Data Point 3</th>
<th>Data Point 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centroid A</td>
<td>0.0</td>
<td>1.0</td>
<td>3.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Centroid B</td>
<td>3.1</td>
<td>2.3</td>
<td>0.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>

By observing Table 6A, it can be seen that Data Point 2 is now located closer to Centroid A, Data Point 3 is located closer to Centroid B and Data Point 4 is also located closer to Centroid B.

Step 5: Cluster each Data Point based on the minimum distance between the Data Point and the updated Centroids.

Similar to Step 3, Data Points 1 to 4 are now clustered as follows:

<table>
<thead>
<tr>
<th>Clustering</th>
<th>Data Point 1</th>
<th>Data Point 2</th>
<th>Data Point 3</th>
<th>Data Point 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
</tr>
</tbody>
</table>

Table 7A: Clustering of Data Points – Iteration 1

Repeating the process described in step 3, the centroids may now be ‘updated’ again. Since Group A now consists of Data Points 1 and 2 and Group B of Data Points 3 and 4 then, the updated Centroids of Group A and Group B may be found as follows:

Centroid A after iteration 1: \(\left(\frac{1+2}{2}, \frac{1+1}{2}\right)\) \(\rightarrow\) Centroid A after iteration 1: \(\left(\frac{3}{2}, 1\right)\) and

Centroid B after iteration 1: \(\left(\frac{4+5}{2}, \frac{3+4}{2}\right)\) \(\rightarrow\) Centroid B after iteration 1: \(\left(\frac{9}{2}, \frac{7}{2}\right)\).

Step 6: Calculate the new distance of each Data Point from each one of the updated Centroids – Iteration 2
The same process as in Steps 2 and 4 is repeated in order to calculate the distance of each Data Point from the updated centroids obtained in Step 5. Hence, the distances now are as presented in Table 8A.

<table>
<thead>
<tr>
<th>Data Point</th>
<th>Data Point 1</th>
<th>Data Point 2</th>
<th>Data Point 3</th>
<th>Data Point 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centroid A</td>
<td>0.5</td>
<td>0.5</td>
<td>3.2</td>
<td>4.6</td>
</tr>
<tr>
<td>Centroid B</td>
<td>4.3</td>
<td>3.5</td>
<td>0.7</td>
<td>0.7</td>
</tr>
</tbody>
</table>

*Table 8A: Calculated distances between Data points 1, 2, 3 and 4 and (i) updated Centroid A (row 1) and (ii) updated Centroid B (row 2) – Iteration 2*

From Table 8A, it can be observed that Data Points 1 and 2 are located closer to Centroid A and Data Points 3 and 4 are located closer to Centroid B (Table 9A).

<table>
<thead>
<tr>
<th>Clustering</th>
<th>Data Point 1</th>
<th>Data Point 2</th>
<th>Data Point 3</th>
<th>Data Point 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Data Point 1</td>
<td>A</td>
<td>Data Point 3</td>
<td>B</td>
</tr>
<tr>
<td>B</td>
<td>Data Point 4</td>
<td>B</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 9A: Clustering of Data Points – Iteration 2*

It can be observed comparing Tables 7A and 9A that all four Data Points have remained in the same cluster. Consequently, there is no need to update the Centroid coordinates and thus, the process has finished.

The clustering results of the k-means algorithm example described above are confirmed by utilising MATLAB’s k-means clustering algorithm; see Figure 2A.
The upper-located black dot corresponds to the Centroid of Cluster B and the lower-located black dot corresponds to the Centroid of Cluster A; Centroid A is located at \((\frac{3}{2}, 1)\) and Centroid B is located at \((\frac{9}{2}, \frac{7}{2})\) as calculated in Step 5. Moreover, the coordinates of the two red dots correspond to Data Points 3 and 4 with coordinates (4,3) and (5,4), respectively and the two blue dots correspond to Data Points 1 and 2 with coordinates (1,1) and (2,1), respectively. The two red dots (i.e. Data Points 3 and 4) belong to Cluster B with centroid \((\frac{9}{2}, \frac{7}{2})\) and the two blue dots (i.e. Data Points 1 and 2) belong to Cluster A with centroid \((\frac{3}{2}, 1)\) (see Table 9A). Thus, the result obtained via the hand calculations is verified via MATLAB software (Figure 2A).

(iii) The Wilcoxon rank sum test

In the following part, an example is provided where Data Sets A and B (Table 10A) are compared via the Wilcoxon rank sum test (Vrije Universiteit Amsterdam, 2017; Wallace, 2004).

<table>
<thead>
<tr>
<th>Data Set A</th>
<th>Data Set B</th>
</tr>
</thead>
<tbody>
<tr>
<td>225</td>
<td>83</td>
</tr>
<tr>
<td>79</td>
<td>52</td>
</tr>
<tr>
<td>225</td>
<td>113</td>
</tr>
<tr>
<td>52</td>
<td>67</td>
</tr>
<tr>
<td>29</td>
<td>165</td>
</tr>
<tr>
<td>98</td>
<td>132</td>
</tr>
<tr>
<td></td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>230</td>
</tr>
<tr>
<td></td>
<td>255</td>
</tr>
</tbody>
</table>

*Table 10A: Data Set A and Data Set B*

The steps followed in order to compare Data Sets A and B utilising the Wilcoxon rank sum test may be summarised as follows:

Step 1: Combine Data Set A with Data Set B, Order combined data and Rank combined data
The elements of Data Set A (DSA) and Data Set B (DSB) are combined and sorted from the lower to the higher values (third and fourth columns of Table 11A).

<table>
<thead>
<tr>
<th>Data Set A (DSA)</th>
<th>Data Set B (DSB)</th>
<th>Combined and Ordered Data Sets A and B</th>
<th>Rank combined Data Sets A and B without considering the ties (i.e. numbers who repeat themselves twice); in this example numbers 52 and 225</th>
<th>Averaged rankings of combined Data Sets A and B</th>
</tr>
</thead>
<tbody>
<tr>
<td>225 (DSA)</td>
<td>83 (DSB)</td>
<td>29 (DSA)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>79 (DSA)</td>
<td>52 (DSB)</td>
<td>48 (DSB)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>225 (DSA)</td>
<td>113 (DSB)</td>
<td>52 (DSA)</td>
<td>3</td>
<td>3.5</td>
</tr>
<tr>
<td>52 (DSA)</td>
<td>67 (DSB)</td>
<td>52 (DSB)</td>
<td>4</td>
<td>3.5</td>
</tr>
<tr>
<td>29 (DSA)</td>
<td>165 (DSB)</td>
<td>67 (DSB)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>98 (DSA)</td>
<td>132 (DSB)</td>
<td>79 (DSA)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>48 (DSB)</td>
<td>83 (DSB)</td>
<td>83 (DSB)</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>230 (DSB)</td>
<td>98 (DSA)</td>
<td>98 (DSA)</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>255 (DSB)</td>
<td>113 (DSB)</td>
<td>113 (DSB)</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>132 (DSB)</td>
<td>132 (DSB)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>165 (DSB)</td>
<td>165 (DSB)</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>225 (DSA)</td>
<td>225 (DSA)</td>
<td>12</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>225 (DSA)</td>
<td>225 (DSA)</td>
<td>13</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>230 (DSB)</td>
<td>230 (DSB)</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>255 (DSB)</td>
<td>255 (DSB)</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

*Table 11A: Combined and Ranked Data Sets A and B*
In the third column, it can be observed that numbers 52 and 225 repeat themselves twice. When repeated data values, such as 52, occur then, instead of using the corresponding ranks, in this case rank 3 and rank 4, the two ranks are averaged as: 
\[
\frac{3+4}{2} = 3.5
\]
Hence, rank 3.5 is used instead of rank 3 and rank 4; see fifth column of Table 11A. Following the same procedure, rankings 12 and 13, which correspond to number 225, are averaged i.e. 
\[
\frac{12+13}{2} = 12.5
\]
and rank 12.5 substitutes ranks 12 and 13.

Step 2: Reorganise combined data into Data Set A and Data Set B, sum the averaged rankings and calculate the median of each Data Set.

Data Sets A and B are reorganised (Table 12A and Table 13A), and their corresponding averaged rankings are summed.

<table>
<thead>
<tr>
<th>Data Set A</th>
<th>Averaged rankings of Data Set A</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>52</td>
<td>3.5</td>
</tr>
<tr>
<td>79</td>
<td>6</td>
</tr>
<tr>
<td>98</td>
<td>8</td>
</tr>
<tr>
<td>225</td>
<td>12.5</td>
</tr>
<tr>
<td>225</td>
<td>12.5</td>
</tr>
</tbody>
</table>

*Table 12A: Data Set A with averaged rankings*

Sum of averaged rankings of Data Set A: \( T_1 = 43.5 \)
Number of samples of Data Set A: \( n_1 = 6 \)
Median of Data Set A: \( \frac{79+98}{2} = 88.5 \)
### Data Set B

<table>
<thead>
<tr>
<th>Data Set B</th>
<th>Averaged rankings of Data Set B</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>2</td>
</tr>
<tr>
<td>52</td>
<td>3.5</td>
</tr>
<tr>
<td>67</td>
<td>5</td>
</tr>
<tr>
<td>83</td>
<td>7</td>
</tr>
<tr>
<td>113</td>
<td>9</td>
</tr>
<tr>
<td>132</td>
<td>10</td>
</tr>
<tr>
<td>165</td>
<td>11</td>
</tr>
<tr>
<td>230</td>
<td>14</td>
</tr>
<tr>
<td>255</td>
<td>15</td>
</tr>
</tbody>
</table>

*Table 13A: Data Set B with averaged rankings*

Sum of averaged rankings of Data Set B: $T_2 = 76.5$
Number of samples of Data Set B: $n_2 = 9$
Median of Data Set B: 113

### Step 3: Test whether the median values of the Data Sets are different at a selected level of significance.

In this step, a Hypothesis test is performed in order to check whether the median values obtained in Step 2 are different at a selected level of significance. For this example, the level of significance has been selected to be $\alpha = 0.05$ for a two-tailed test.

The Null Hypothesis, $H_0$, holds if: $R_{\text{LOWER}} < T_1 < R_{\text{UPPER}}$ and the Alternative Hypothesis, $H_A$, when $T_1 \geq R_{\text{UPPER}}$ and $T_1 \leq R_{\text{LOWER}}$.

Note that for $\alpha = 0.05$ , $R_{\text{UPPER}}$ and $R_{\text{LOWER}}$ correspond to the upper 2.5% and lower 2.5% critical values of the Wilcoxon Rank Sum Test and $T_1$ is the sum of rankings of the Data Set with the smaller number of samples, for this case Data Set A. The values of $R_{\text{UPPER}}$ and $R_{\text{LOWER}}$ can be found from the Critical Values for Wilcoxon Rank Sum Test table (Athienitis, 2018). For this example, for $n_1 = 6$, $n_2 = 9$ and $\alpha = 0.05$ (two-tailed test) then, $R_{\text{LOWER}} = 31$ and $R_{\text{UPPER}} = 65$ (The University of Auckland, 1997).
Since $R_{\text{LOW}} (= 31) < T_1 (= 43.5) < R_{\text{UP}} (= 65)$, the Null Hypothesis, $H_0$, cannot be rejected.

Summarising, although the median values of Data Sets A and B are different, this difference is not significant at the $\alpha = 0.05$ level.

Note that the results obtained via hand calculations have also been verified through MATLAB software.
VI. MEQ Polarity Responses for Module: Chassis Development and Telemetry for academic year 2016-17.