AN EVALUATION OF THE IMPACT OF PROJECT-BASED LEARNING ON STUDENT ENGAGEMENT IN THE SIX SIGMA GREEN BELT QUALITY MODULE AT GALWAY-MAYO INSTITUTE OF TECHNOLOGY: A CASE STUDY

by

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A thesis submitted in the Thesis in Education Science module, in partial fulfilment of the requirements for the Master of Arts in Teaching & Learning programme in the Galway-Mayo Institute of Technology

Research Advisory Panel

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ABSTRACT

Comprehensive and in-depth discipline content knowledge and professional, practical skills are critical in the engineering domain. At the same time, soft skills, such as communication, teamwork, critical thinking and problem-solving have become increasingly important at the workplace. Lecturers in the Department of Mechanical and Industrial Engineering at GMIT spare no efforts to ensure their students are equipped with the right skills, competences and knowledge. Project-based learning (PBL) is a teaching strategy proven to enable students acquire both hard and soft skills. The PBL approach, moreover, has the potential to increase motivation and interest in learning, which, consequently, lead to increased student engagement, as well as enhanced learning and academic performance. The aim of this research is to evaluate the impact of PBL on student engagement in the Six Sigma Green Belt Quality module at GMIT. The case study methodology and mixed methods for data collection were employed. The findings suggest that PBL has a positive impact on student engagement. It contributes to increased involvement in class activities and engagement in collaboration with peers, it motivates students to learn and it has a positive impact on their learning satisfaction. The analysis revealed further positive impacts of PBL such as enhanced, deep learning and increased knowledge. PBL, moreover, gives students more control over their learning, transforming them in independent learners. The study has limited generalisability due to the small scale of the study and the selection of participants, which was based on convenience and purposive sampling and not a random selection of students. However, it offered the researcher an in-depth understanding of the impact of PBL on student engagement in the engineering module of Six Sigma Green Belt Quality and the way this impact is perceived by the students themselves.

KEYWORDS: project-based learning, student engagement, higher education, Six Sigma, case study, mixed methods

DEDICATION

I dedicate this thesis to my family.

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1. CHAPTER ONE: INTRODUCTION

The current environment is a globalised world which is inundated by technology and is constantly facing the challenge of improving and gaining more and diverse competencies. Educators at all levels are required to be the first to adapt to these challenges and to provide students with the right skills, competences and knowledge that will allow them to cope with and even excel in such an environment. At Galway-Mayo Institute of Technology (GMIT), lecturers in the Mechanical & Industrial Engineering Department aim to equip students with hard skills, i.e. good knowledge and professional, practical skills, which are critical in the engineering domain, but also with soft skills, including communication, teamwork, critical thinking and problem-solving, which are considered increasingly important at the work place (Casner-Lotto & Barrington, 2006). One teaching strategy proven to enable students acquire knowledge and equally develop soft skills is project-based learning (PBL) (Konopka et al., 2015). PBL offers students the possibility to actively participate in a project related to real-life situations (Hung et al., 2012) and has the potential to increase motivation and interest in learning (Bilgin et al., 2015). These characteristics respond to the new generation's concern with motivation level and their desire to be taught in class as close to real-life as possible, as highlighted in a recent study (Au-Yong-Oliveira et al., 2018).

1.1. RATIONALE FOR THE RESEARCH

The author is a lecturer in the Mechanical & Industrial Engineering Department at GMIT, a third level institute of education in the west of Ireland. All of the department's programmes are designed for a well-balanced use of lectures, laboratories and tutorials delivered in small groups, with the aim to engage students and motivate them. However, despite continuous, collective efforts at department level to enhance student engagement, some students disengage with the challenging engineering content. One reason could be the large diversity of our students in terms of background and the level of understanding that they bring to class (Brinson, 2015). Another cause may be the large number of students enrolled on each programme as a result of the national and regional proactive promotion of STEM in the last few years (Department of Education and Skills, 2019).

All of these provocations call for a constant review and adjustment of pedagogy and practice, in line with best practice, not least, the placing of learners at the core of the teaching and learning process, the promotion of the cognitive development of the students, and the enhancement of learners' motivation and interest (Daniela & Lytras, 2018). Literature shows a clear relationship between student engagement and student motivation, student satisfaction and retention, as well as academic performance (Fredricks et al., 2004; Kahu, 2014; Zepke, 2014). In parallel, research indicates that traditional didactic teaching, where the teacher is imparting knowledge and students are receiving it, cannot meet all the requirements that are coming from students and industry, therefore educators are increasingly transforming their role from that of delivering knowledge, as 'experts' in the field, to largely passive learners, to supporting students to construct their own knowledge, whilst taking advantage of the new technologies available (Au-Yong-Oliveira et al., 2018). New approaches to teaching and learning can lead to improved learning experiences and effective learning (Pritchard, 2017; Chen & Yang, 2019), acquisition of soft skills (Perrenet et al., 2000; Sharma et al., 2020), improved student engagement (Durkin, 2016) and increased motivation (Guo et al., 2020; Hung et al., 2012). One approach based on the student-centred concept is PBL, "an inquiry-based instructional method that engages learners in knowledge construction by having them accomplish meaningful projects and develop real-world products" (Guo et al., 2020). There is plenty of evidence that this approach offers all the benefits listed above for STEM subjects, both in lower-level and higher-level education (Guo et al., 2020; Lee et al., 2014). Guo et al. (2020) have reviewed an impressive number of studies on PBL but only a very small number of studies focus on the impact PBL has on student engagement within engineering subjects, and none addresses the specific engineering context of 3rd year mechanical engineering students at GMIT. This study will address that gap.

Informed by literature and previous PBL studies in engineering, a real-world simulated project was added to the Six Sigma Green Belt Quality elective module for 3rd year mechanical engineering students. This offered students the possibility to actively participate in a project related to real-life situations involving problem-solving and decision-making, and to use Minitab, a piece of software largely used in industry by Six Sigma practitioners. The project was specifically designed for this study with a view

to meet the learning outcomes of the Six Sigma Green Belt Quality module, equip students with the skills required in industry, enhance student engagement and develop more student-centred teaching practices.

In light of these adaptations to the module, in this study the author will investigate the following research question: what impact has a PBL strategy on student engagement in the Six Sigma Green Belt Quality module? The study will provide a deeper understanding of the phenomenon with a view to informing future practice.

1.2. AIMS & OBJECTIVES

The aim of this research is to evaluate the impact of PBL method on student engagement in the Six Sigma Green Belt Quality module in GMIT.

The main objectives of the study are:

- Objective 1: To clarify key terminology relevant to the study, such as ‘student engagement’ and ‘project-based learning’ (PBL).
- Objective 2: To critically evaluate literature related to PBL and its implementation in engineering programmes with a view to informing the research design.
- Objective 3: To perform a literature analysis of the learning theories that underpin PBL as a learning tool with a view to informing the pedagogical framework for a PBL strategy.
- Objective 4: To design and conduct a GMIT case study aimed at evaluating the impact of PBL method on student engagement in the Six Sigma Green Belt Quality module.
- Objective 5: To analyse the research findings, in conjunction with the literature, and present recommendations for further study.

1.3. RESEARCH METHODOLOGY

The research was carried out from an interpretivist position and included elements of pragmatism and positivism. Section 3.3 discusses the dominant research paradigms in educational research and justifies the selection of the paradigm selected to support this research. Interpretivism was considered the most suitable paradigm for the study

as it closely aligns to the research objective, which seeks to understand the participants' views on their experience of PBL and how PBL impacts on their engagement with Six Sigma learning. However, the practical-based and applied nature of the research also demanded a pragmatic approach, therefore there is also a pragmatic and positivist influence.

Case study was deemed the most suitable research methodology for this study. Section 3.4 outlines two possible options – case study and action research – and justifies the chosen methodology of case study. It facilitated the in-depth exploration and description of the phenomenon (the impact of PBL on student engagement within one specific GMIT engineering module) and helped the researcher understand the specific impact that PBL had on student engagement in the case study – by means of analysing multiple student perspectives.

The study employed mixed methods for data collection, as discussed in detail in section 3.5. This choice helped capture the complexity of the phenomenon under study and the multiple views of the phenomenon, by using quantitative and qualitative approaches in combination, in a phased sequence. The specific data collection tools used in the three-phase study included observation (in phase 1, during a class dedicated to project work) followed by a questionnaire (in phase 2, a week after project class) and interview (in phase 3, a week later). The interviews were carried out after processing the initial data in order to collect more in-depth information so that the researcher could understand the participants' experience with PBL and gather as many points of view as possible in relation to the way they perceived engagement. The adoption of mixed methods and a triangulated approach assured the research was more valid and reliable. There are several ethical issues related to this study, especially related to the dual role of the researcher (researcher-lecturer). These aspects are discussed in section 3.6.

1.4. SCOPE & LIMITATIONS

This research used a case study to evaluate the impact of PBL on student engagement with the lectures and tutorials in the 3rd year Six Sigma Green Belt Quality module of the Mechanical Engineering programme at the Department of Mechanical and

Industrial Engineering, GMIT. The scope of this research was to obtain students perceptions of how the implementation of the PBL impacted on their engagement with learning for this module. The results of the study were intended to inform the teaching strategy for the Six Sigma Green Belt Quality module as well as other engineering modules.

Due to time constraints (1 year for research and thesis completion), the research was confined to a relatively low number of participants (22 students). The choice of the module was informed by findings in literature (suitability of PBL to 3rd years – see section 2.5) as well as the practicality of the circumstances: students were timetabled in a computer laboratory, they had access to numerous sources of information (e.g. internet, GMIT library website) and a dedicated software (i.e. Minitab), therefore it was properly set up for the purpose of the research. It was also possible that the research be carried out in a different scenario, in light of the constraints that have arisen due to COVID-19: moving teaching and assessment partially or, for certain periods of time, totally online.

The scope being limited to a particular module and to a low number of research participants, a limitation of the study (as indeed with any case study) is the inability to generalise beyond the specific case under analysis. However, this study will provide directions for an improved and more engaging teaching strategy on the part of the author and will also offer a foundational model for researching the impact of PBL on student engagement beyond this single case, to other Engineering or STEM modules within GMIT, and beyond.

1.5. THESIS STRUCTURE

The thesis is organised into six chapters and an epilogue. Chapter 1 presents the context of the study and introduces the aim and objectives. The research methodology is presented, and the scope and limitations of the study are discussed.

Chapter 2 reviews the literature relevant to the study. The terms ‘student engagement’ and ‘project-based learning’ were clarified and indicators for student engagement measurement were identified. An overview of PBL in the context of the active learning approach to pedagogy is followed by an analysis of PBL application to engineering

programmes and its influence on student engagement. The chapter ends with an analysis of the teaching and learning theories underpinning PBL: constructivism, constructionism and behaviourism.

Chapter 3 focuses on the research methodology and methods. It discusses in detail the methodological framework adopted for this study and justifies the selection of the paradigm approach, research methodology and data collection methods – observation, questionnaire and interview.

Findings from the case study carried out at GMIT are discussed in Chapter 4. The chapter starts with an overview of the data analysis methods used in the study, followed by the findings presented thematically, according to the main themes of student engagement: impact of PBL on behavioural engagement, impact of PBL on emotional engagement and impact of PBL on cognitive engagement.

Chapter 5 analyses the research findings, in conjunction with the literature. The key findings of the study in relation to PBL impact on student engagement are organised into emergent sub-themes along the three main themes of behavioural engagement, emotional engagement and cognitive engagement. The subsequent sections discuss how the study performed in terms of reliability and validity, and the contribution and limitations of the study.

Chapter 6 concludes this thesis. It summarises the study, highlights the main findings, and ends with recommendations for further research. The epilogue presents the author's final thoughts on the study.

2. CHAPTER TWO: LITERATURE ANALYSIS

2.1. INTRODUCTION

This chapter presents a literature analysis of student engagement and the use of PBL in education, with focus on the application of this approach to engineering subjects and its impact on student engagement. The purpose is to inform the research design and the pedagogical framework for the PBL strategy.

The chapter starts with the literature analysis methodology. The subsequent sections are structured along the three main areas that support objectives 1, 2 and 3 of the study. Firstly, the author clarifies the terminology used in the study, particularly in relation to student engagement and PBL, as depicted in objective 1. Therefore, sections 2.3 and 2.4 present a review of student engagement literature and, respectively, PBL literature and the rationale for the definitions chosen for this study. In light of objective 2, section 2.5 discusses student engagement through PBL. Finally, a range of pedagogical theories underpinning PBL as a learning tool is critically evaluated in section 2.6, supporting objective 3.

2.2. LITERATURE ANALYSIS METHODOLOGY

The literature analysis started with a selection of databases available at the GMIT library. Several databases were searched, including Science Direct, Academic Search Complete, IEEE Explore and Google Scholar, and top ranked journals in the field of education and engineering were selected. The initial set of literature was selected from articles published in journals with high SJR indicator and H index (Scimago, 2021), including but not limited to *Journal of Engineering Education, Journal of Higher Education, Research in Higher Education, Journal of Educational Research* or *International Journal of Educational Research*. The Research@THEA, an open access repository containing research from all the Irish Institutes of Technology, was also consulted in order to find conference proceedings.

Key words such as ‘project-based learning’, ‘student engagement’, ‘student centred learning’ and ‘higher education’ were used to identify key literature. The initial set of

literature was refined, retaining only the articles directly related to the objectives of the study. Following a systematic snowballing procedure (Wohlin, 2014), further literature was identified via the reference list and citations of individual articles. When reference was made to well-known concepts, the original material (book or article) was consulted. Information was extracted at the same time as the paper was classified as 'included for further consideration' in accordance with the objectives of the research (Wohlin, 2014). The reviewed literature highlighted themes further explored in this chapter, which were used as the foundation for building the case study at GMIT in order to evaluate the impact of PBL method on student engagement in the Six Sigma Green Belt Quality module.

2.3. STUDENT ENGAGEMENT

The idea of engaging students in learning and teaching is not new. It has been in literature for decades (Tyler & Smith, 1942) and has evolved from engaging students in the classroom (Brophy, 1983; McIntyre et al., 1983) to a more complex concept. At the lower level, in the classroom, student engagement refers to the degree of attention, interest, curiosity, or even passion that students show when they are learning, which increases the level of motivation they have to learn and progress in their education (Great Schools Partnership [GSP], 2016). At a higher level, student engagement means involving students in the governance and decision-making processes in education, in the design of curricula or programmes or school policies, concept known as 'students as partners' in teaching and learning (GSP, 2016; Cook-Sather et al., 2014; Dunne & Zandstra, 2011; Healey et al., 2014). The interpretation of student engagement adopted for this study is student engagement in the learning process at the lower level, in the classroom, as most suitable for the aim and objective 4 of the study, as stated in section 1.2.

Although student engagement has been researched for a long time, there is not a clear agreement on conceptualising engagement. Some researchers consider student engagement encompasses in-class as well as non-academic aspects of student experience (Barkley, 2010), others argue that it is a process requiring out-of-classroom experiences (Kahu, 2014), whilst other authors consider the place of learning – in-class or out-of-class – is not important (Pickford, 2016), thus making difficult the

distinction between terms – student engagement, student involvement, community engagement (Vuori, 2014). Another debate among researchers refers to who has the responsibility to initiate student engagement – is it the school or the student (Pickford, 2016). Despite the multitude positions and opinions, student engagement is generally conceptualised as students' connection to learning and the learning environment (Marx et al., 2016). The definition adopted for this study is:

> Student engagement is the extent to which students actively engage by thinking, talking, and interacting with the content of a course, the other students in the course, and the instructor (Dixson, 2015).

Literature reveals many benefits of engaging students in learning. It fosters student learning e.g. enhanced enthusiasm in the classroom, students becoming more active learners and taking more responsibility for their own learning (Cook-Sather et al., 2014), better academic performance and personal development (Carini et al., 2006; Kuh et al., 2006; Zingier, 2008). It can also assist student retention (Mandernach, 2015; Braxton, 2008; Sousa, 2015). Indicators of student engagement are discussed in the next section.

2.3.1. Indicators of Student Engagement

Some researchers define student engagement along three dimensions: behavioural, emotional and cognitive (Kuh, 2003; Ginty & Boland, 2016; Mandernach, 2015); others simply recognise these aspects by different names: behavioural, affective and cognitive (Anderson, 2017; Fredricks et al., 2004); whilst others identify four factors that illustrate student engagement: skills engagement, emotional engagement, participation (or interaction) engagement and performance engagement (Dixson, 2015; Handelsman et al., 2005). Performance engagement refers to doing well on assessments and exams, and getting good grades (Handelsman et al., 2005). This aspect was not part of the aim of this research; therefore, the first categorisation of student engagement was adopted in this study, along the behavioural, emotional and cognitive dimensions. The three aspects are defined as follows: behavioural engagement is the degree to which students are actively involved in learning activities, emotional engagement refers to students' affective reactions to learning, and cognitive engagement is the degree to which students spend mental effort to understand and master content (Fredricks et al., 2004; Kahu, 2014; Zepke, 2014; Trowler, 2010).

Students can engage either positively or negatively along these three dimensions (Trowler, 2010). Scholars have tried to identify indicators that correspond to each type of engagement. Indicators of behavioural engagement include effort and time spent engaging in learning activities (Kahu, 2014; Fredricks et al., 2004; Trowler, 2010; Kuh, 2009), as well as interaction with lecturer, peers and other members of college staff (Kahu, 2014; Coates, 2007; Zepke, 2014). Among indicators of emotional engagement researchers mention interests, values and attitudes towards learning and a perceived sense of belonging within a learning community (Kahu, 2014; Fredricks et al., 2004; Trowler, 2010). Finally, indicators of cognitive engagement include: active construction of knowledge (Coates, 2007; Kuh, 2009), persistence to overcome academic challenges (Kuh, 2009; Fredricks et al., 2004; Trowler, 2010), critical thinking (Coates, 2007), motivation to learn (Zepke, 2014; Lester, 2013) and self-regulation (Lester, 2013; Fredricks et al., 2004). Although each aspect of student engagement has distinct characteristics, there are some overlaps – see Figure 1 – and an indicator could correspond to more types of engagement.

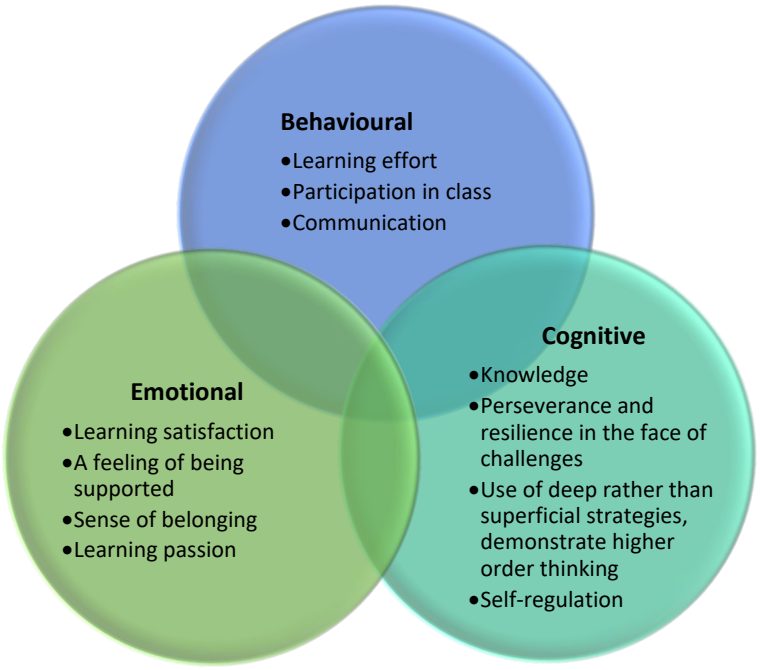


Figure 1. The Three Dimensions of Student Engagement and Measurement Indicators, adapted from (Schindler et al., 2017)

The indicators selected to inform the design of data collection tools in Chapter 3 are presented in Figure 1. Indicators of behavioural engagement comprise learning effort

(before and after class), participation in class (paying attention to lecturer's comments, asking questions, answering lecturer's questions, helping other students) and communication (verbal, email, via MS Teams, via Moodle). Indicators of emotional behaviour include learning satisfaction (desire to learn, interest in learning, enjoyment of learning, successful outcome), a feeling of being supported (by lecturer, by colleagues), sense of belonging (feelings of membership and acceptance to the college learning community, to their group) and learning passion (willingness to exert mental effort, enthusiasm, curiosity, joy). Cognitive engagement can be evaluated along the following dimensions: knowledge, perseverance and resilience in the face of challenges, use of deep rather than superficial strategies, demonstrate higher order thinking and self-regulation (the extent to which students demonstrate control over their learning actions). A relevant concept in the context of student engagement in learning, teaching and assessment is student-centred learning (SCL). It is discussed in the next section.

2.3.2. Student-Centred Learning

Literature suggests that SCL has the potential to make learning more engaging for students (Zepke & Leach, 2010). The SCL concept goes back decades, but more recently it is associated with the work of Piaget (constructivism) and Knowles (humanist theory) (Nagaraju et al., 2013; Attard et al., 2010), which will be discussed in more detail in section 2.6. As the name suggests, the students are driving the learning process and are responsible for their own learning, whilst the lecturer acts only as a facilitator (McDonald, 2012; Brown Wright, 2011). Various authors use different phrases to express the concept of SCL: 'student-centred instruction' (Collins & O'Brien, 2003); 'learning-centred assessment' (Huba & Freed, 2000); 'peer led team learning' (Tien et al., 2001); 'team-based learning' (Michaelson et al., 2004); 'active learning' (Bonwell & Eison, 1991) to name just a few. The team that worked on the 'Time for a New Paradigm in Education: Student Centred Learning' European project suggested a definition that summarises all the aspects that characterise SCL:

> Student-Centred Learning represents both a mindset and a culture within a given higher education institution and is a learning approach which is broadly related to, and supported by, constructivist theories of learning. It is characterised by innovative methods of teaching which aim to promote learning in communication

with teachers and other learners and which take students seriously as active participants in their own learning, fostering transferable skills such as problem-solving, critical thinking and reflective thinking (Attard et al., 2010).

Based on evidence showing enhanced learning and engagement, various strategies and tools are proposed to improve SCL, such as the use of information technology in- and outside of classroom (Attard et al., 2010), active learning, use of case studies, group project work, project presentations, field trips (Froyd & Simpson, 2010) and alternative assessment strategies (McDonald, 2012).

Active learning methodologies engage students in the learning process through activities in the classroom, instead of passively listening to the lecturer. Usually these methods involve higher order thinking and, quite often, teamwork (Freeman et al., 2014). Active learning comprises a wide and varied set of methods/techniques that require students to perform activities by being aware and responsible for what they do, therefore acquiring knowledge, skills, values and attitudes (Konopka et al., 2015). Using individual learning strategies, students develop and apply knowledge to solve problems, and generate new knowledge using cognitive processes. Using a teaching strategy involving cooperative learning, students work together in groups and develop social skills as well as knowledge. Carvalho and Williams (2009) and Konopka et al. (2015) gathered a good amount of evidence of contribution of active learning to academic success in STEM disciplines.

An active learning method that has come across as used successfully, especially in STEM disciplines, is PBL. As opposed to traditional teaching methods, PBL permits students to acquire not only knowledge, but also other skills such as problem-solving, team spirit, capacity to learn new topics, autonomy etc., which are so valuable to any employer. That statement is supported by many examples of higher education level institutions, engineering in particular, that adopted active learning successfully (Kolmos & de Graaff, 2014; de Graaf & Kolmos, 2007). As literature suggested PBL as one of the methodologies and strategies that can enhance student-centred learning and student engagement, the next section critically assesses literature discussions of PBL.

2.4. PBL: GENERAL LITERATURE PERSPECTIVES

PBL is a strategy with roots in constructivism and constructionism and it is related to problem-based learning. Some consider that there is a very thin line between the two methods, they are usually used together and complement each other (Donnelly & Fitzmaurice, 2005). In a PBL approach, students actively participate in a project, usually related to real-life situations, and cooperate with their group members to reach a specific goal or result. They learn through data collection, problem solving, discussions, presentation of results and reports (Hung et al., 2012). Authors have identified a number of characteristics of PBL, which are summarised in Figure 2.

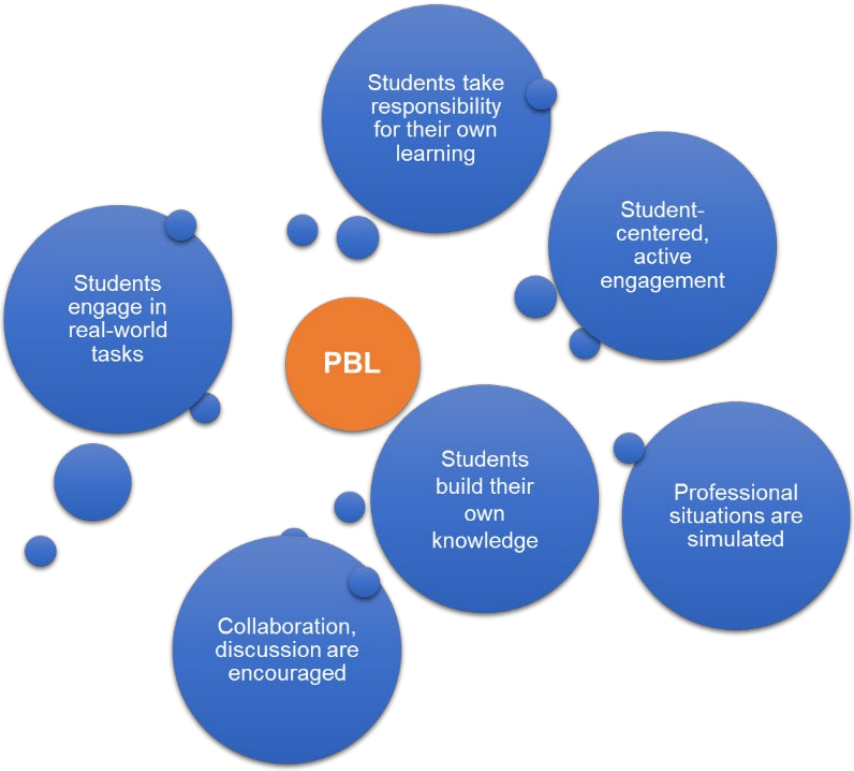


Figure 2. Characteristics of PBL, based on (Hung et al., 2012; Bilgin et al., 2015; Brundiers & Wiek, 2013)

As Figure 2 shows, using real-life scenarios, giving students independence in making their own decisions, encouraging collaboration and discussion, PBL helps students create their own knowledge instead of being taught – ideas originated from constructivism, as it will be further discussed in section 2.6 – and has many positive benefits to students. Bilgin et al. (2015) reviewed numerous studies that prove contribution of PBL to students' academic achievement, improved attitude towards

science courses, but also increased motivation and problem-solving capability (Bilgin et al., 2015). However, the move from a deliverer of knowledge to a facilitator of learning, effectively conducting a PBL activity so to motivate and engage students is not easy; it will pose many challenges to educators. Lee et al. (2014) acknowledge that sourcing a real-world project that is also academically rigorous can be difficult, therefore sometimes lecturers might try to find community partners, which is not an easy task either. An important aspect of PBL is the design of learning tasks in line with the learning objectives the lecturer wants to achieve, but also promoting motivation for learning. Moreover, new assessment strategies, compatible with PBL learning, must be used, as PBL involves group work (Lee et al., 2014). Another aspect emphasised by other studies is related to the difficulties encountered by students in a PBL approach. Hung et al. (2012) indicated that students do not always understand their responsibility for their own learning, and it can be difficult for them sometimes to make the connection between their prior knowledge and the new knowledge. As literature did not offer a single comprehensive definition of PBL, the author proposed the following working definition for this study:

> PBL is a teaching strategy that aims to achieve student learning via participating in a project designed to address a real-world problem. Students work in a small team and the lecturer provides ongoing instruction, guidance and support. Formative assessment is conducted during learning and summative assessment is completed at the end of the project, after learning has occurred.

Having examined PBL more generally, the next section specifically evaluates literature related to the implementation of PBL within engineering programmes, with particular emphasis on its impact on student engagement, in line with objective 2 of the research.

2.5. ENGAGING STUDENTS THROUGH PBL IN ENGINEERING

Although PBL is a well-established learning method, which has been successfully applied in STEM subjects, there is not extensive evidence of its application in engineering. A number of studies have been investigated and the findings are summarised in this section.

Many times PBL in engineering is used in response to difficulties some faculties/departments are confronted with, such as retention, drop outs, decreasing student motivation (Eugene, 2006) or industry requirements for both professional and

soft skills (Balve & Albert, 2015), and are applied at course level, usually multi-disciplinary projects. There are also cases when PBL is used at module level, either in engineering or science. The author has reviewed a number of studies that present both situations in Table 1. The studies are evaluated from two perspectives: (1) contribution of PBL to student achievement in terms of professional and soft skills, and (2) contribution of PBL to student motivation and engagement in learning.

Table 1. Examples of PBL Initiatives in Engineering

Project-based learning initiative	Student achievements	Research methods
The Learning Factory at the Heilbronn University **(Balve & Albert, 2015)** – 16 ECTS credits, an entire semester. It covers the entire product development process, very similar to real-world situation. Three aspects of student achievement are assessed: (1) teamwork; (2) overall company performance and (3) individual performance.	• Communication skills • Ability to work in a team • Ability to work autonomously • Presentation skills • Problem-solving skills • Interdisciplinary thinking • Academic writing skills	• Questionnaire • Feedback workshops • Observation
The Quad Bike project at Hyderabad Institute of Technology and Management **(Sharma et al., 2020)**. It covers all four major steps in making a product – conceptualisation, design, testing, manufacturing – and it involves knowledge of various disciplines: mathematics, physics, materials, computer-aided design.	• Technical skills • Teamwork • Team management skills • Real-world problem-solving skills • Leadership	Research methods were not discussed
Various theme projects in 1st and 2nd year at the Universite´ Catholique de Louvain in Belgium **(Eugene, 2006)**. The project is multi-disciplinary, is realistic from an industrial point of view and covers conception, modelling, making, experimental validation and diagnosis (example: the realisation of an electronic flash for camera, a mobile robot). Team evaluation as well as individual contribution.	• Teamwork • Communication skills • Autonomy and spirit of initiative • High enthusiasm and motivation • Self confidence • Report writing and presentation skills	• Questionnaire • End of course test to check 'understanding' and 'applicability'
'I am the energy-saving master' PBL with digital storytelling tasks for science class at an elementary school in southern Taiwan **(Hung et al., 2012)**. The experiment looked at how the PBL with digital storytelling could effectively enhance the students' science learning motivation, problem-solving competence, and learning achievement.	• Problem-solving competences • Science knowledge • Enhanced science learning motivation • Changed learning attitude • Team cooperation, work capability, and thinking capacity	• Experiment • Interviews
PBL at University of Indianapolis **(Lee et al., 2014)**. The university is using a PBL model supported by Buck Institute for Education: projects are carefully planned, managed and assessed to ensure students acquire key knowledge but also soft skills. Lecturers in various departments participated to the study. The focus was on classroom experience. Challenges for lecturers identified: assessment, need for continuous improvement, engaging community partners.	• Collaboration skills, despite student being reluctant to group work at the beginning • Student engagement and increased motivation in their own learning mainly due to the involvement of community partners • Self-directed learning	• Interviews • Observation • Surveys

As seen in Table 1, all PBL initiatives were successful in terms of achieving the main goal, that of constructing professional knowledge, but also acquiring soft skills, such as teamwork, collaboration, communication, problem-solving, as well as enhanced engagement and motivation. This finding aligns with the aim of the study presented in this thesis.

Not all initiatives were in engineering, some were in science and technology, but science is a very important subject in engineering, so the PBL experience is relevant. An interesting PBL experience is presented in Perrenet et al. (2000). They looked at a combined problem-based learning and PBL and their suitability to engineering. The study found that PBL is more suitable in 3rd and 4th year of study as the focus is on application and integration of knowledge rather than on acquisition. In the early years a problem-based approach would be more suitable. This finding has influenced the choice of the module for the PBL study conducted in this research, in line with objective 4.

Guo et al. (2020) have reviewed a large number of studies on PBL in higher education, looking at cognitive outcomes (acquired knowledge), affective outcomes (student perception) and behavioural outcomes (skills and engagement) and how they were measured. They found that student engagement was evaluated by various methods: interviews, questionnaires, journals as well as artefacts (assessed by rubrics). These findings informed the decision regarding the data collection methods selected in section 3.5 for this study.

2.6. LEARNING THEORIES UNDERPINNING PBL

In order to use an innovative education solution such as PBL, supported by technology or not, one should have a clear understanding of the underpinning learning theories and, in relation to that, the role of the educator in the classroom, as well as applicable teaching methods to the particular subject matter. Constructivism is seen as dominant in science education (Agarkar & Brock, 2017), possibly in engineering as well. PBL, as an active learning strategy, has emerged from constructivism (Savasa et al., 2012). However, elements from other learning theories such as constructionism and behaviourism have been used in engineering and they have the potential to enhance

student engagement (Agarkar & Brock, 2017). This section investigates how these three main learning theories can support the design of learning tasks and assessment strategies that are compatible with PBL, in line with objective 3 of the study.

2.6.1. Constructivism

Constructivist theories in teaching and learning examine the way mind constructs knowledge (Schrader, 2015) and are based on the work of two pioneers in cognitive development – Jean Piaget (Piaget & Cook, 1952) – and social development – Lev Vygotsky (Vygotsky, 1978), although Piaget and Vygotsky did not explicitly link their theories to education. The emphasis is on student activity; students construct their own knowledge by experiencing things and reflecting on their experiences (Daniela & Lytras, 2018), instead of the traditional mode of transferring knowledge from teachers to student (Biesta, 2013). Learners have to activate prior knowledge ('scheme') when interpreting new experiences – process called 'assimilation' – and create new knowledge when exposed to experiences that don't fit with existing schemes – process called 'accommodation' (Kay & Kibble, 2015). Although many educators have embraced the constructivist approach to teaching, some researchers criticise it for the minimal amount of teacher-provided instruction, which is not effective for novice learners (Kirschner et al., 2006). Further critiques of constructivism claim that it promotes group thinking, ignoring the individuality of students (Gupta, 2011) and overlooks the importance of contextual factors in learning environments (Ackermann, 2001).

Many researchers argue that constructivism is a 'theory of learning' and not a 'theory of teaching' (Biesta, 2013; Richardson, 2003) and the role of the teacher is to support and facilitate learning (Richardson, 2003; Biesta, 2013; Ozer, 2004) and create the process of learning rather than the product of learning (Olsen, 1999). Therefore, constructivism promotes the move towards student-centred learning, being the basis of a large variety of teaching methods where the students are driving the learning process and are responsible for their own learning. Examples of such methods are PBL, experiential learning, problem-based learning, case-based learning, inquiry-based learning and discovery-based learning. They all have proved to be effective in classroom or laboratory (Makgato, 2012; Hean et al., 2009). Savasa et al. (2012) show

in their study that integrated activities (from various disciplines) based on constructivist teaching and learning processes have a positive effect on students' academic success and self-confidence. These findings complement Von Glasersfeld's, who suggests that self-confidence is a pre-requisite to motivation to learn and, therefore, engagement (Von Glasersfeld, 1998).

The project used as support for the PBL method in this research is an authentic learning scenario as it replicates a 'real-world' problem. Students learn through their attempt to solve the problem and interpret the results. These are critical elements of the constructivist learning theory, according to (Jonassen, 1998).

2.6.2. Constructionism

Based on Piaget's constructivism, Papert built another learning theory: constructionism. The two terms can be confusing, Papert himself trying to clarify: "constructionism – the N word as opposed to the V word" (Papert & Harel, 1991). The simplest definition of constructionism, as Papert himself expressed it, is 'learning-by-making' (Papert & Harel, 1991). Indeed, constructionism expands the constructivism theory, knowledge built by the learner, by adding the idea of artefact construction and learner interaction with their artefacts (Parmaxi & Zaphiris, 2014), be it a sand castle or a theory of the universe (Papert & Harel, 1991). According to constructionism, students learn best if they find the knowledge they need by themselves when building something that others can see, examine and critique (Daniela & Lytras, 2018). Although Vygotsky studied extensively the role of social and cultural interactions in the learning process, constructionism brings constructivism to another level by considering, as Ackermann (2001) points out, three aspects: (1) the role external aids play at higher level of a learner's development; (2) the types of external aids (media) and (3) the type of initiative taken by the learner in designing their artefact. Constructionism also acknowledges various learning styles and representations of knowledge (Kafai & Resnick, 2008).

The main benefit of constructionism to engineering subjects is it promotes concreteness (Wilensky, 1991). Often engineering students are confronted with understanding difficult concepts. When building an artefact, which is the main goal of an engineering project, the learner gets engaged with their own creation, as well as

the concept or piece of knowledge needed to build the object and this process makes the knowledge concrete, no matter how abstract that concept may seem (Wilensky, 1991).

The PBL initiative used in this study involves abstract concepts of probabilities and statistics. Students apply them to a real-life scenario using a software package that offers the possibility to visualise and interact with the charts and graphs they created (an 'artefact'). That aspect has the potential to motivate students and engage them with their learning.

2.6.3. Behaviourism

Behavioural learning theories define learning as behaviour modification or new behaviours that appear as a response to stimuli (Anderson & Dron, 2011; Conole et al., 2004; Agarkar & Brock, 2017). Behaviourism is based on Pavlov's dog study on the formation of conditioned reflexes by means of conditioned and direct stimuli (Pavlov, 1927) and Thorndike's 'law of effect', which is the responses that produce a satisfying effect are more likely to occur again in that situation than responses that produce a discomforting effect (Thorndike, 1927; Gray, 2011). Moreover, Skinner showed that response was affected by reinforcement elements, which can lead to the achievement of what is called 'operant behaviour' (Skinner, 1938; Lecas, 2006; Peel, 2005).

Starting as an approach to psychology rooted in animal study (Pavlov, 1927; Thorndike, 1927; Skinner, 1938), behaviourism evolved into a systematic learning theory based on repetition and drill (Taba, 2013). As opposed to the theories reviewed in sections 2.6.1 and 2.6.2, the educator has the central role in behaviourism and focuses on modification of the student's behaviour by manipulating the environment and by stimuli such as praise or punishment (Skinner, 1968; Thurlings et al., 2013). Central to the behaviourist learning process is reinforcement (Conole et al., 2004) and trial and error (Hean et al., 2009; Conole et al., 2004).

Behaviourism received many critiques. Some did not agree with extending the findings from experiments on animals to human learning, which is a much more complex process (Stewart, 2012; Agarkar & Brock, 2017). Others criticised behaviourism for

being centred on the stimulus-response principle; the central and authoritarian role of the teacher who would simply impart knowledge, without any consideration to the thinking and reflecting process were also subjected to criticism (Peel, 2005; Stewart, 2012). Another drawback of behaviourism is the fact that it fails to develop critical thinking and other skills that are important in the current learning environment and it can induce boredom to students (Agarkar & Brock, 2017). Although the behaviourist perspective was heavily criticised (especially by constructivists) (Agarkar & Brock, 2017; Peel, 2005; Stewart, 2012), many pedagogies having their origin in the behaviourist approach, are still used successfully in the classroom.

Some aspects of the behaviourist pedagogies can be applied to the design of the learning activities and the assessment strategy for the PBL initiative of this study, such as the decomposition of complex tasks into a sequence of steps, the extensive use of feedback to guide the student towards achieving targets or the use of incentives and penalties (Agarkar & Brock, 2017; Stewart, 2012).

2.6.4. The Pedagogical Framework for the PBL Study

As Ackermann (2001) stated in his study, what learning theories offer is ideas on (1) how to re-think education, (2) create new learning environments, and (3) use new tools, media and technologies in teaching and learning. In order to show how the PBL strategy was supported by the learning theories discussed in section 2.6, and to create a strong pedagogical framework for the design of the learning activities and the assessment strategies that are suitable for PBL, the author has summarised the three underpinning theories in Table 2, under three headings: contribution to the design of the PBL strategy, contribution to student-centred learning, contribution to student engagement and contribution to skill development.

Table 2. Pedagogical Framework

Learning theory	Contribution to design of PBL strategy	Contribution to student-centred learning	Contribution to student engagement	Contribution to skill development
Constructivism	• Real-life scenario • Problem-based • Lecturer as facilitator of learning	Yes	Yes	• Problem-solving • Critical thinking • Soft skills • Professional skills
Constructionism	• Construction of an artefact • Transforming abstract into concreteness • Use novel media	Yes	Yes	• Problem-solving • Critical thinking • Soft skills • Professional skills
Behaviourism	• Decomposition of tasks • Feedback	No	No	• Professional skills

The learning theory underpinning the PBL strategy for this study is constructivism, with elements from constructionism and behaviourism. Table 2 shows that the theories that stand out as compatible with PBL are constructivism and constructionism. Both theories can contribute to student-centred learning and student engagement, whilst helping students acquire the skills necessary in industry. Constructivism dictated the design of the learning activities, as it promotes the use of a real-life scenario and problem-solving: students are requested to find the root cause of a problem, based on the analysis of a set of data, as illustrated in the project description in Appendix 1. Also rooted in constructivism is the role of the lecturer as facilitator of learning rather than teacher. Students were provided with material and software and were encouraged to work and discuss with their peers, the lecturer being simply a facilitator. Borrowed from constructionism are the construction of visual aids for the analysis, similar to the artefacts of constructionism, and the application of abstract concepts to real situations. Students created charts and graphs that helped visualise trends and problems that otherwise could not be identified. There are elements of the behaviourist theory that offered ingredients for a successful construction of the PBL strategy, such as the decomposition of complex tasks into a sequence of smaller tasks, and the extensive use of feedback to guide the student towards achieving targets.

The selection of the module was also part of the PBL strategy. Six Sigma Green Belt Quality is a discipline at the intersection between science and engineering. It is a very

practical module and teaches students techniques that are applied in industry on a day-to-day basis. It relies on problem-solving and explaining complicated mathematical concepts by application to real-life scenarios.

2.7. CONCLUSIONS

This chapter presented a literature analysis in line with objectives 1, 2 and 3 outlined in section 1.2. The chapter started with a description of the literature analysis methodology, which shows a systematic and coherent approach to the entire study. Sections 2.3 and 2.4 addressed the first objective of the study, namely it clarified the terms ‘student engagement’ and ‘project-based learning’ in the context of this research. In section 2.3 a definition at the lower level of student engagement – in the classroom – was adopted and indicators for its measurement were identified along three dimensions: behavioural, emotional and cognitive engagement. These indicators were further used to inform the design of the data collection tools, as discussed in Chapter 3. Section 2.4 critically assessed literature discussions of PBL and, as no clear, comprehensive definition was found, a working definition for this study was proposed.

Section 2.5 addressed objective 2 of the research. It identified the PBL method as an active learning strategy that has been applied successfully in STEM subjects. Literature indicated that PBL is an effective teaching strategy to promote student engagement, as well as constructing professional knowledge and soft skills, such as teamwork, collaboration, communication and problem-solving. Finally, section 2.6 has reviewed three learning theories with a view to support the PBL strategy and to create a strong pedagogical framework for the design of the PBL learning activities and assessment. It was concluded that the theory compatible with PBL is constructivism with constructionist and behaviourist elements. These theories influenced the design of the PBL strategy used in this study to evaluate its impact on student engagement, as depicted in section 3.5. The next chapter discusses another important aspect of the study, the research methodology.

3. CHAPTER THREE: RESEARCH METHODOLOGY & METHODS

3.1. INTRODUCTION

This chapter addresses Objective 4 of the research, to design and conduct an original primary research case study aimed at evaluating the impact of PBL method on student engagement in the Six Sigma Green Belt Quality module (see section 1.2). The chapter starts with an outline of the methodological framework of the research. The study has adopted a question-driven approach: the nature of the research question (see section 1.1) suggested the philosophical approach, the research methodology and the method for data collection. Section 3.3 explores three research paradigms used in educational research and provides the rationale for the selection of the paradigm that guided the research, in line with the research question and objectives, namely the interpretivism, with influences from pragmatism and positivism. The paradigm informed the research methodological framework, namely the case study, which was selected as the most suitable framework for the research, as argued in section 3.4. The chapter continues with the case study design and selection of data collection methods and ends with ethical considerations in section 3.6.

3.2. METHODOLOGICAL FRAMEWORK

In order to have a rigorous research design, the researcher has to consider the nature of the phenomenon under study, as well as the ontological and epistemological bases for conducting the research (Cohen et al., 2018). Some scholars believe that any research should have a paradigm-driven approach, as a research paradigm is the "lens through which a researcher looks at the world" (Kivunja & Kuyini, 2017) and it determines the research methodology that will be used, how data will be collected and analysed. Other researchers argue that the starting point can be a problem or a question that needs answer, therefore the starting point does not have to be a paradigm but rather the research question (Punch & Oancea, 2014). This thesis adopts the latter approach, question-driven research, and then identifies the paradigm by which the research will be pursued. A methodological framework of the research is presented in Figure 3.

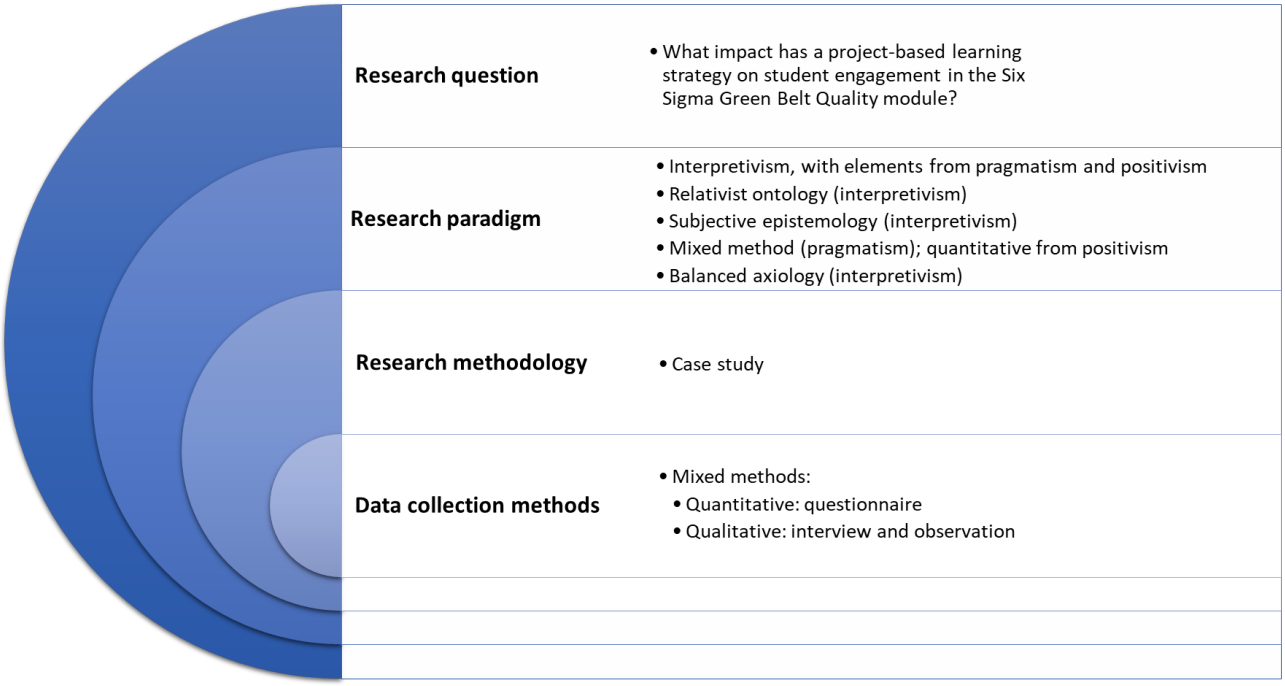


Figure 3. Research Methodological Framework

At the top level of the methodological framework is the research question, what impact has a PBL strategy on student engagement. At the next level is the philosophy in which the research is located. The author adopted an interpretivist approach to this research, as it is appropriate for the research question, as formulated in Chapter 1. Interpretivists seek to understand a phenomenon under study, looking for meaning in the subjective experiences of the participants, as discussed in greater detail in section 3.3.1. Although the research was carried out from an interpretivist position, there are elements of pragmatism and positivism, especially in the methodology area. The case study as research methodology emerged from the research paradigm and in line with Objective 4 of the research. Mixed methods were deemed most suitable for data collection. The following section will discuss several research paradigms and will justify the choice for the study, in line with the research question, as well as the author's beliefs and principles.

3.3. RESEARCH PARADIGMS

The term paradigm in educational research means a researcher's 'worldview' (Mackenzie & Knipe, 2006), the perspective or a set of principles that guide how a

researcher sees the world and how they interpret and act within that world. Most authors agree that a paradigm comprises of four elements: ontology, epistemology, methodology and axiology (Punch & Oancea, 2014; Cohen et al., 2018; Lincoln & Guba, 1985; Kivunja & Kuyini, 2017). The author has summarised the four components and the types of questions each element is addressing in Figure 4.

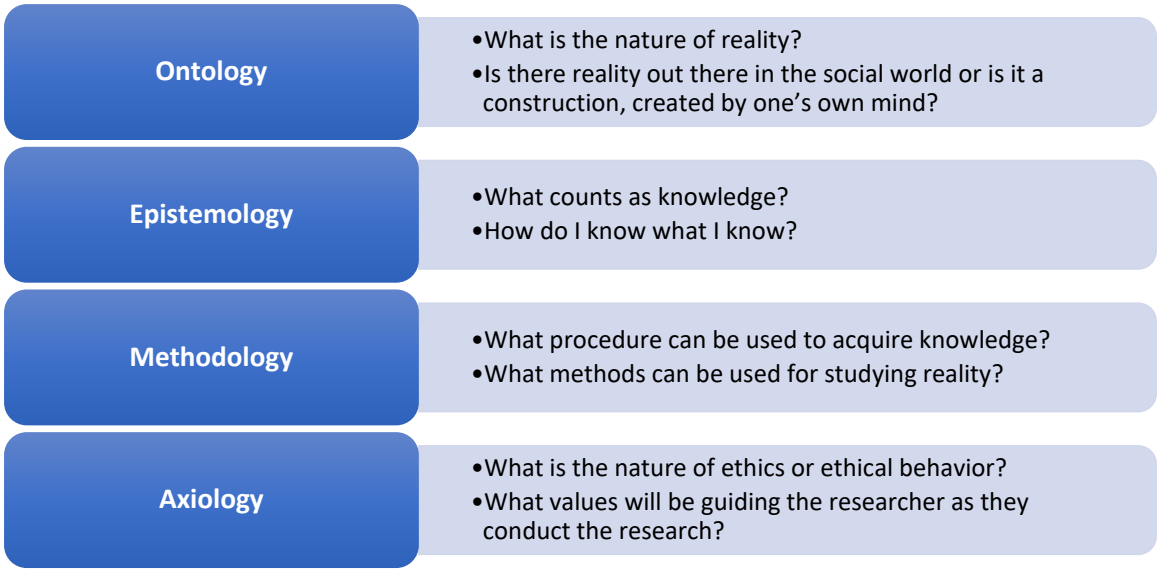


Figure 4. Four Elements of a Research Paradigm

Ontology is concerned with the form and nature of reality, it is related to our assumptions about reality, if it is objective or subjective (Hatch & Cunlife, 2006). It helps the researcher understand the problem under investigation and interpret the meaning of data collected (Kivunja & Kuyini, 2017). Closely related to ontology is epistemology, as epistemological assumptions often arise from ontological assumptions (Sale et al., 2002; Cohen et al., 2018). Epistemology explores the relationship between the researcher and what can be known (Punch & Oancea, 2014). Slavin (1984) identified four sources of knowledge: (1) intuitive knowledge (forms of knowledge such as beliefs, faith, and intuition); (2) authoritative knowledge (data gathered from people in the know, books, leaders in organisation); (3) logical knowledge (emphasis on reason as the surest path to knowing the truth) and (4) empirical knowledge (knowledge is best derived from sense experiences, and demonstrable, objective facts). Epistemology influences the way the researcher will discover knowledge in the social context the investigation is carried out (Kivunja &

Kuyini, 2017). Furthermore, methodology articulates the process followed in research in order to gain knowledge and refers to research design, methods, procedures and approaches (Keeves, 1997). It enables the researcher to answer the research question and to make a contribution to knowledge. The fourth component of a research paradigm is axiology, which refers to the ethical issues that need to be considered when research is carried out: moral, cultural, intercultural and fairness issues (ARC, 2015). Axiology helps the researcher to conceptualise, set up the values that will guide the study.

This section will further discuss the dominant research paradigms in educational research and will justify the selection of the paradigm selected to support this research. Although paradigms do not necessarily drive the research, they have implications on the choice of research methodology and methods (Kivunja & Kuyini, 2017; Punch & Oancea, 2014). There is a multitude of paradigms in educational research, but the author is discussing only the most relevant to this research: interpretivism, positivism and pragmatism.

3.3.1. Interpretivism

Interpretivism appeared in response to the belief that a single reality exists independent of our senses and human behaviour is governed by universal laws (Rehman & Alharthi, 2016; Cohen et al., 2018). Interpretivism (or constructionism) advances socially constructed multiple realities, hence the name ‘constructivism’. The interpretivism paradigm adopts a relativist ontology, a subjectivist epistemology, a naturalist methodology and a balanced axiology. People construct their own worlds and views and the focus is on understanding the individual and their interpretation of the world around them, rather than the point of view of the observer (Cohen et al., 2018; Kivunja & Kuyini, 2017). As Grix (2004) states, the researcher is not detached from the participants to the research and the external reality is contaminated by their worldviews, concepts and background. Interpretivists are more likely to use qualitative methods to get the multiple realities and the approach to data analysis is inductive (Rehman & Alharthi, 2016). A balanced axiology assumes that the results of the research will reflect the values of the researcher, attempting to present a balanced report of the findings (Kivunja & Kuyini, 2017). The validity criteria for interpretivist

research, commonly accepted, are credibility, dependability, confirmability and transferability and were originally proposed by Guba (1981). Interpretivism has been criticised mainly for the lack of objectivity (Grix, 2004) and the impossibility to generalise the findings of a research, the interpretivist research being context-specific (Cohen et al., 2018).

The aim of this research is to evaluate the impact PLB has on student engagement in the Six Sigma Green Belt Quality module by understanding the participants' attitude and experience, the way they construct their views and interpretation of the PBL experience. The researcher creates an interpretation of the participants' interpretation. This aligns with the relativist ontology and the subjectivist epistemology of interpretivism; therefore, the interpretivist paradigm was a suitable lens to view this research. However, researchers depend on their own knowledge and judgement when interpreting phenomena and data, on their senses when making observations, according to Hammersley (2011) cited in Cohen et al. (2018). The same data can offer different interpretations or conclusions; therefore, it calls for a balance between subjectivity and objectivity. Two more philosophies are investigated in order to identify elements that might help achieving this balance.

3.3.2. Positivism

Although positivism has its roots in Ancient Greek philosophers, it is mainly associated with the work of Auguste Comte (Cohen et al., 2018). To characterise positivism along the four dimensions of a paradigm, its ontology is realism, its epistemology is objectivism, its methodology is experimentation, and its axiology beneficence. For positivists there is a single reality which exists independently, whether it is perceived or not, and we perceive the world directly, approximately as it is (Searle, 2015). According to Bryman (2008), all true knowledge is scientific and can be measured by scientific methods and the researchers' own personal attitudes do not affect the scientific research. Positivism is mainly associated with experimental methodology, which employs the scientific method that relies mainly on hypothesis testing to establish causality between variables, and collection of numerical data (Cohen et al., 2018; Rehman & Alharthi, 2016). The beneficence axiology requires that research should aim at maximising good outcomes not only for the research project and the

research participants, but for humanity in general (Martens, 2015). The validating criteria for research in a positivist approach are internal validity, external validity, reliability and objectivity (Burns, 2000; Yin, 2009). Having been criticised due to its low applicability to the human behaviour, a derivative of the positivist paradigm has appeared – postpositivism (Cohen et al., 2018). Postpositivism still considers that reality is out there to be studied, but accepts that reality can never be fully understood; but at best, only approximated, according to Guba (1990), cited in Kivunja and Kuyini (2017).

The author finds the objectivism and scientific method of the positivist paradigm suitable for scientific and engineering research projects and has used it in the past. However, the research presented in this thesis is centred on the employment of the PBA (project-based learning) to an engineering module and focuses on the impact of this strategy on student engagement. That involves human behaviour and individuals' perception, which does not concur with the pure objectivist epistemology of the positivism paradigm. Moreover, the study does not offer the external validity or generalisability required by a good quality positivist research, as it is confined to a specific module and to a small number of students. Therefore, positivism as a dominant approach was deemed unsuitable for this research. However, some elements of positivism were incorporated: it was considered that the use of quantitative methods for data collection would benefit the validity and reliability of the study and would bring some objectivity that interpretivism is lacking – hence balance.

3.3.3. Pragmatism

Pragmatism originated in the philosophical movement in the United States in the early 1870s, which involved philosophers, psychologists and jurists such as Charles Sanders Peirce, Oliver Wendell Holmes Jr. and was further developed by philosophers and educationists such as John Dewey (Kaushik & Walsh, 2019). Pragmatism appeared as a reaction to both positivism and interpretivism and rejects the dualism of objectivity and subjectivity, as well as the exclusivist view of each philosophy on reality and knowledge (Maxcy, 2003). The pragmatic ontology is non-singular reality. Many authors cited by Kaushik and Walsh (2019) agree that pragmatists accept that there is an objective reality which exists independent of human experience, and there

is the reality that each individual interprets based on their own beliefs, habits and experiences. The epistemological position of pragmatism is relational, with roots in Dewey's 'theory of inquiry' – beliefs and actions are connected through a process of inquiry, which has the aim to create knowledge with a view to change and improve existence (Goldkuhl, 2012; Biesta, 2013; Morgan, 2014). On a paradigm continuum, pragmatism is situated somewhere between positivism and interpretivism in terms of methodology. Pragmatists believe that the best methodology and methods to use are the ones most suitable to address the research question, the ones that solve the problem, therefore propose the mixed method methodology (both quantitative and qualitative) (Creswell & Plano Clark, 2017; Goldkuhl, 2012). Pragmatism advocates for a value-laden axiology (conducting research that benefits people) (Kivunja & Kuyini, 2017).

The author can see a clear connection with the pragmatic paradigm, as a method of inquiry for practical-minded researchers, intended to solve practical problems in the real-world (Creswell & Plano Clark, 2017; Maxcy, 2003). Another characteristic of pragmatism that resonates with the author's beliefs is the positioning of the research question at the core of the research approach, the method following from the question, be it quantitative or qualitative or a mix. The quantitative and qualitative mixed methods approach used by pragmatists was considered more enriching to meet the research objective of evaluating the impact of PBL on the students' engagement. However, the aim of the study is understanding the phenomenon rather than engaging in change, which is an attribute of pragmatism (Goldkuhl, 2012). Therefore, an exclusively pragmatic approach would not be entirely suitable for this research study. Nevertheless, elements of the pragmatic paradigm were blended into the approach of this research, including the mixed methods of data collection and the fact that this research will inform the decision to make practical changes to the researcher's teaching strategy at a later stage.

Based on the literature reviewed in section 3.3, the author has summarised the main characteristics of the three dominant paradigms in educational research in Table 3, which helped formulate the rationale for the approach adopted for this study.

Table 3. Summary of the Three Dominant Paradigms for Educational Research

Paradigm	Ontology	Epistemology	Methodology	Axiology	Validation criteria	Research methodologies suited to paradigm	Data collection methods	Suitability for the aim of the research
Interpretivism	Multiple realities, that must interpreted from different angles	Subjectivism – individuals create their own knowledge	Naturalist methodology - induction	Balanced report of the findings	• Credibility • Dependability • Confirmability • Transferability	• Naturalist • Narrative inquiry • Case study • Grounded theory • Phenomenology • Hermeneutics • Ethnography • Phenomenography • Action research	Qualitative, such as: • Unstructured interview • Observation • Narratives	Yes
Positivism	Single reality which exists independent of our perception	Objectivism - knowledge is scientific and can be measured by scientific methods	Experimental methodology - deduction	Research should aim at maximising good outcomes for humanity in general	• Internal validity • External validity • Reliability • Objectivity	• Experimental • Quasi-experimental • Correlational • Causal comparative • Randomized control trials • Survey research	Quantitative, such as: • Questionnaire • Focus groups • Interviews • Statistical analysis	In a very small degree
Pragmatism	Non-singular reality, constantly interpreted in light of its usefulness in improving the individual's situation	Relational - inseparable link between human knowing and human action	Mixed method methodology – the ones most suitable to address the research question	Research that benefits people	Not clearly identified	• Naturalist methodology • Narrative inquiry • Case study • Phenomenology • Ethnography • Action Research • Experimental • Quasi-experimental • Causal comparative	A mix of the above	Partially

The aim of the research is to evaluate the impact of a new teaching method, the PBL, on student engagement in the Six Sigma Green Belt quality module. This aim aligns with the role of the interpretivist researcher who is engaged in understanding students' attitudes and experiences and interpreting what they are thinking or the meaning they are making of the experience of changing the teaching practice, as suggested by Table 3. Locating the research in a particular paradigm exerts significant influences on the choice of methodology to be used in the study, which is going to be discussed in the next section.

3.4. RESEARCH METHODOLOGY

The research methodology describes the type of research, the approaches and techniques, and the data collection methods used throughout the study, taking into account their practical applicability to this research, as well as assuring the reliability and validity of the research (Cohen et al., 2018; Punch & Oancea, 2014). At the same time, the research methodology must concur with the research paradigm, the research question and the type of research.

Section 3.3 presented three research paradigms used in educational research and ended with the rationale for using an interpretivist approach with elements of pragmatism and positivism for this research. As depicted in Table 3, there are four research methodologies common to interpretivism and pragmatism: narrative inquiry, ethnography, case study and action research. Moreover, the research question outlined in Chapter 1, which aligns with the aim of the research, seeks to evaluate the impact of an intervention (new teaching method using PBL) on the participants to the study (students). According to Cohen et al. (2018), case studies, action research and experimentation are among the research methodologies suitable for this type of question. As experimentation is suitable to a positivist approach, it was not explored any further, as not deemed appropriate to an interpretivist study. The third factor that needs to be considered in the selection of the research methodology is the type of research. The present study is an empirical (or exploratory) research (Habib, 2014; Zikmund, 2011) undertaken to observe and capture experiences in order to understand the impact of PBL on student engagement in engineering subjects, Green Belt Six Sigma Quality in particular. The case study is one of the methodologies used

in empirical research, which can provide empirical evidence in the form of qualitative and quantitative data (Habib, 2014). These criteria narrowed down the number of methodologies applicable to the research to two – case study and action research – which will be investigated in the next section.

3.4.1. Case study vs. Action Research

Case study is a research methodology appropriate for describing, explaining, understanding, predicting and/or controlling processes related to an event, an individual, a group, an organisation, an industry, or even a nation (Woodside, 2017; Case & Light, 2011). Its origins are in qualitative approaches to research embedded in interpretivism and constructivism and has evolved into an inductive methodology that uses detailed systematic procedures to analyse data (Harrison et al., 2017). The case study methodology has been accepted as a robust research method relatively recently. Yazan (2015) argues that case study, in comparison with other research methodologies, is capable of inquiring into the case that interests researchers, whilst Merriam (2009) describes the methodology as particularistic (the focus is on a specific entity), descriptive and heuristic (it enables the researcher to understand and describe the findings). The case study methodology has been used in education quite extensively, for various purposes such as to evaluate curriculum design and innovation, to determine the impact of educational programs or to explore and evaluate educational programs, as summarised by Harrison et al. (2017). It was mainly criticised for the unsystematic procedures (Yin, 1981) and the impossibility to produce generalisations for an entire population (Stake, 1994).

Action research is usually done by practicing professionals who are searching for very practical, applied solutions rather than theoretical (Edwards & Willis, 2014). Action research goes back to times after the Word War II when Lewin thought the focus of research should be on ‘action’, developing knowledge that leads directly into action (Lewin, 1948). One of the main characteristics of action research is the involvement of stakeholders in the research to solve their problem. Edwards and Willis (2014) exemplify types of problems action research can solve according to two paradigms – positivism (for example, well-defined problems of practice that require well-defined technical solutions) or interpretivism (e.g. local problems identified by the participants

that need local solutions or problem and solution that may change as dialog, reflection and evaluation help participants refine their understanding). No matter which theoretical strand defines action research, it has some specific characteristics that all authors accept: it is carried out in the field where the problem exists, it is an iterative process, it focuses on finding solutions to the problem and relies on the researcher's deep involvement (Edwards & Willis, 2014; Calder & Foletta, 2018; Lawson et al., 2015). The action research methodology permits the researchers' development of their knowledge by testing theory but also generates theory. Action research have been used in education in many instances. Calder and Foletta (2018) present a collection of examples, which prove that action research has the potential to improve teaching and learning. The main criticisms of action research are its subjectivity due to the deep personal involvement of the researcher, its uncontrollability over the environment being studied and its limited external validity (Kock, 2004; Mackenzie et al., 2012).

Both research methodologies – case study and action research – offer an in-depth understanding of the real-world phenomenon under study. A case study starts with the researcher's interest in a particular phenomenon, whilst an action research starts with a problem in a particular situation/community (Blichfeldt & Andersen, 2006). A case study investigates the problem/phenomenon in order to get a deep understanding, whilst an action research offers understanding as well as a solution to the problem. The author's main goal was to understand the impact of a new teaching strategy based on PBL on student engagement, and not to solve a problem or to take any action, therefore the case study was considered more appropriate for this study. The next section will discuss the case study methodology in more detail and will show the link with the research question and the objectives of the study.

3.4.2. Case Study

Cohen et al. (2018) have synthesised the various definitions of a case study into one that captures most characteristics of the case study:

> It is the detailed examination of a small sample and an in-depth investigation of a specific, real-life project, policy, institution, program or system from multiple perspectives in order to catch its complexity and uniqueness (Cohen et al., 2018).

Yin (2009) adds that the case should be set within its context, whilst Yazan (2015) mentions that a case study is an empirical inquiry which addresses the “how” or “why” questions regarding the phenomenon of interest. Moreover, Hamilton et al. (2012) argue that a case study focuses on the idea of a bounded system (such as a class, a school or a community) and uses more than one perspective. Mauldin (2020) emphasises the uniqueness of this research methodology in that it can be used both in an interpretive manner to build theories or in a positivist manner to test theories. In their comprehensive review of case studies in literature, Harrison et al. (2017) remark that all scholars in the field recommend the use of multiple methods to collect and analyse data in case study research, the most commonly employed methods being interviews, focus groups, observations and exploring artefacts. Referring to case studies in education, Cohen et al. (2018) cite Bassey (1999) who states that:

> Case studies investigate interesting aspects of an educational activity, programme or institution, or system mainly in its natural context and within an ethic of respect for persons, such that plausible, trustworthy explanations and interpretations can be offered after collecting sufficient data in exploring the significant features of the cases (Cohen et al., 2018).

The characteristics of a case study presented above are reflected in this research as follows: (1) it focused on a group of third year mechanical engineering students studying the Six Sigma Green Belt Quality Module at GMIT; (2) it involved a detailed examination of the small sample in the context of a change of teaching method, i.e. the implementation of PBL; (3) the project aimed to understand multiple perspectives of the individuals involved in the study on the impact PBL has on student engagement; (4) the core elements of the research are the exploration and description of the phenomenon which is the impact of PBL on student engagement; and (5) mixed methods (quantitative and qualitative) were used for data collection.

Literature reveals many classifications of case studies. Yin (2009) divides case studies into three categories, according to their outcome: exploratory (pilot studies, the starting point for other studies), descriptive (provide a narrative of a natural phenomenon that occurred) and explanatory (focus on the explanation for a phenomenon or problem). That classification echoes Merriam’s three types – descriptive, interpretative and evaluative (Merriam, 1998). Another case study scholar, Stake (1995), cited by Roller and Lavrakas (2015), identifies the following three types of case study: intrinsic (the

focus is on the understanding the particular case rather than generating theories), instrumental (using the case study to understand a broader phenomenon of interest) and multiple or collective (there are groups of instrumental studies, with the purpose of getting a better picture of the phenomenon). Cohen et al. (2018) mention the work of another prominent methodologist in the case study area, Stenhouse (1985), whose typology consists of neo-ethnographic (single in-depth investigation of a single case), evaluative (a single case or group of cases studied at such depth as the evaluation of policy or practice will allow), action research (field work, offering an alternative approach) and educational (school case studies undertaken by teachers).

Based on Yin's classification, this research mirrors the characteristics of a descriptive case study because it is used to describe an intervention (PBL method) and the real-life context in which it occurred (teaching the Six Sigma Green Belt Quality module). According to Merriam, this study is interpretative as the researcher is seeking to interpret the students' perception of the impact PBL has on their engagement with the module. Moving on to Stake's typology, the author would classify this study as intrinsic, because it is used to understand the particular situation (the impact of the new teaching method, PBL, on student engagement), although the case plays a supportive role, facilitating the understanding of the impact of PBL on student engagement in engineering in general. The case is examined in depth, its context is scrutinised and the activities detailed in order to understand the phenomenon better with a view to inform future practice. Furthermore, according to Stenhouse, the study would fit under the umbrella of educational case studies, being undertaken by the actual lecturer who wants to get a deeper understanding of the phenomenon, using observation and analysis.

The case study produces an in-depth analysis of the phenomenon in question and offers high internal validity (Gagnon, 2010). However, due to the specificity of the case study, external validity (replicability by another researcher) and generalisability are problematic (Stake, 1994). The problem of generalisation can be addressed to some extent by triangulation, i.e. using the case study in conjunction with mixed methods (both quantitative and quantitative) for data collection, repeated at different time periods (Gagnon, 2010; Stake, 1994). The use of triangulation offers, at the same time, a deep understanding of the phenomenon (Woodside, 2017). The mixed methods

were used for data collection, as recommendations in literature suggest and this approach is discussed in the next section.

3.5. MIXED METHODS FOR DATA COLLECTION

Many authors classify case study as qualitative inquiry because it explores and seeks to understand the experiences from the perspective of those involved (Merriam, 2009; Cresswell, 2014). A case study employs qualitative methods such as observations, interviews, focus groups, document and artefact analysis and, many times, the researchers' own subjective reflections on their perception and interpretation (Harrison et al., 2017). At the same time, most scholars agree that a mix of methods for data collection will enable a more holistic and comprehensive understanding of the case under study (Yazan, 2015; Cohen et al., 2018), be it a combination of quantitative and qualitative methods, as positivists and pragmatists would claim (Yin, 2009), or a mix of qualitative methods, as recommended by interpretivists (Merriam, 2009; Stake, 1995). Moreover, Cohen et al. (2018) raise the issue of complementarity versus supplementarity in mixed methods, leaving the decision on a method to be used to complement or supplement the research to the researcher. Mixed methods are viewed by different writers not only as a data collection method, but also as a paradigm, an approach or a methodology (Cohen et al., 2018). In this thesis, mixed methods will be referred to as a method defined by (Creswell & Plano Clark, 2017):

> As a method, it focuses on collecting, analysing, and mixing both quantitative and qualitative data in a single study or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone (Creswell & Plano Clark, 2017).

The study presented in this thesis employed mixed methods for data collection for a number of reasons: (1) to capture the complexity of the phenomenon under study and the multiple views of the phenomenon; (2) to complement the subjective nature of the qualitative interpretivist research with the use of quantitative methods; (3) to increase the validity and reliability of the study through triangulation; (4) to best address the research question as formulated in Chapter 1. This choice mirrors those of other research studies of PBL in engineering (see Table 1 in Chapter 2) and supports the evaluation of the impact on student engagement along the three dimensions of

engagement – behavioural, emotional and cognitive – as identified in section 2.3. The data collection methods employed by this study are observation, questionnaire and interview. Some of the instruments were purely qualitative (interview), others were mixed: questionnaire, which included Likert scale response to statements (quantitative) and multiple-choice questions, as well as open-ended questions (to capture the qualitative data); observation – although qualitative in nature, also included a quantitative element. Table 4 shows how the data collection methods align to the research aim and main themes.

Table 4. Alignment of Data Collection Methods to Research Objective and Themes

Research aim	Research themes	Indicators	Data collection methods		
			Quantitative & Qualitative	Qualitative	
			Questionnaire	Observation	Interview
Evaluate the impact of PBL on student engagement	Behavioural engagement	Learning effort	☑	☑	☑
		Participation	☑	☑	☑
		Communication	☑	☑	☑
	Emotional engagement	Learning satisfaction	☑	☑	☑
		Feeling of being supported	☑	☑	☑
		Sense of belonging	☑	☑	☑
		Learning passion	☑	☑	☑
	Cognitive engagement	Knowledge	☑	☑	☑
		Perseverance	☑	☑	☑
		Self-regulation	☑	☑	☑

The study was organised in three phases: (1) phase 1, during class dedicated to project work, when participants were observed; (2) phase 2, a week after project class the participants were distributed the questionnaire; and (3) phase 3, a week later, when some students were interviewed. The next sub-sections discuss the selection of the site and the participants to the study, followed by the design of the three data collection methods and, related to that, piloting the tools.

3.5.1. Selection of Site and Sampling

The aim of this research is to evaluate the impact of PBL method on student engagement in the Six Sigma Green Belt Quality module at GMIT, therefore the research site chosen was GMIT Dublin Road. This study is looking at PBL from an interpretivist perspective, namely how it influences student engagement along three dimensions: behavioural, emotional and cognitive, as depicted in section 2.3. The participants to the study were Mechanical Engineering students who opted for the Six Sigma Green Belt Quality module in year 3. The module is suitable for PBL as it teaches various methods, tools and techniques for problem solving and continuous improvement, and is very much anchored in industry.

As stated in the previous section, the researcher wanted to get a deeper understanding of the phenomenon with a view to inform future practice. The intention was to understand the impact of PBL on student engagement in the Six Sigma module, and not to generalise to the wider population, therefore there is no need to describe quantitatively a relationship between the sample and the population. In consequence, the researcher opted for convenience sampling, a non-probability sampling method that involves data collection from population members who are conveniently available to participate in study (Saunders et al., 2012). According to Cohen et al. (2018), it is frequently used in case study research, being characterised by simplicity, ease of research and suitability for data collection in a short period of time (Saunders et al., 2012). The disadvantage of convenience sampling is that the sample does not represent other groups, it only represents itself, but that is acceptable for the type of research carried out. A number of 37 students were taking the module at the time of the study. Due to special circumstances (COVID-19), the access to the GMIT buildings was restricted and the module was delivered fully online at the time of data collection. All students were invited to participate and had access to the Participant Information Leaflet (see Appendix 2) and Consent Form 1 (see Appendix 3), which were uploaded on MS Teams. Of the 37 students, 22 volunteered to participate in the study and confirmed by returning a positive response to an MS Form, whilst 3 students decided not to participate. The rest did not respond.

3.5.2. Observation Design

Observation is an essential tool in medicine, psychology, social sciences, also used extensively in education research (Shuttleworth & Wilson, 2009; Punch & Oancea, 2014). It is hard to find a clear definition of observation in literature, however many researchers agree with a "systematic recording of observable events, facts, behaviours, artefacts, routines in a natural setting" (Baker, 2006; Cohen et al., 2018). The unique strength of observation, sometimes called 'un-manipulated study' (Shuttleworth & Wilson, 2009), is its potential to provide more authentic data than other research methods because what people say they do might be different than what they really do (Cohen et al., 2018). This data collection tool has some disadvantages: it is time consuming and prone to bias that may result from selective observation, selective recording of information, or the subjective interpretation of situations (Baker, 2006). Great caution and reflexivity must be exerted in order to enhance the rigour and trustworthiness of the study (Barrett et al., 2020).

Observation often requires the researcher to adopt various roles and to use a number of techniques to collect data, but no matter the degree of involvement with the study group, the researcher must always remember their primary role as a researcher and remain detached enough to collect and analyse data relevant to the problem under investigation (Baker, 2006). In this study, the double identity of the observer (researcher and lecturer) poses a number of ethical issues, one of them being the risk of depriving students of class time in favour of the research (see section 3.6), therefore a balance between the two had to be sought. The need to pilot a structured observation cannot be overemphasised, as Cohen et al. (2018) advise. The observation tool was subjected to a few iterations, including an improvement after being piloted in class (see section 3.5.6) and a final improvement to suit online course delivery (Xharavina et al., 2020; Prior & Miller, 2011).

Observation is classified based on various criteria. The most common classifications have been compiled by Cohen et al (2018), which concur with other authors (Ciesielska et al., 2018; Punch & Oancea, 2014; Baker, 2006). According to these classifications, the observation in this study is overt (students were informed in advance about the process and they were asked to sign the Consent Form 1 – see

Appendix 3), direct (the researcher observed the participants directly) and semi-structured (the researcher recorded observation on a predefined template but also took notes). The observation protocol was designed according to guidance in literature. Firstly, as it is impossible to observe everything at once, it was important to decide on the main goal of the observation, what to observe in order to achieve that goal, how many participants, how to record the incidence of the factors being studied and their frequency (Ciesielska et al., 2018; King & Stahl, 2020; Cohen et al., 2018). Secondly, an observation sheet was created – see Appendix 4. As literature suggested (Kelly et al., 2020; Hamre et al., 2013), it was organised into three domains, each further defined by multiple indicators, where the incidence of the factors that characterise student engagement along the three main themes – behavioural, emotional and cognitive – was recorded. Table 5 is mapping some of the observed factors against the engagement indicators determined in section 2.3. Some items were recorded as they emerged (for example, a student was asking a question), others were checked at each visit to the breakout room (for example, a long pause or excited speech).

Table 5. Examples of Observed Factors that Show Student Engagement along the Three Themes

Student engagement themes	Indicator example	Factor example
Behavioural	Participation in class	Student is sharing their screen Student helps his peers
	Communication	Student discusses project-related issue with a peer Student asks lecturer a question
Emotional	Learning satisfaction	Student seems to show energetic involvement in discussion Student uses positive emoticons
	Learning passion	Student seems to express enjoyment Student talks with enthusiasm
Cognitive	Knowledge	Student is able to do the analysis Student is able to interpret the results
	Self-regulation	Student is searching for additional information Student identifies their own mistakes

The third component of observation design is note taking. As suggested by literature, notes were taken immediately to avoid subsequent reinterpretation of what happened and described what was observed rather than making judgements (Ciesielska et al.,

2018; King & Stahl, 2020). Notes were taken immediately after class, typing or using the ‘dictate’ tool available in Microsoft Word.

The observation was organised during week 16, over three sessions, one with each of the three groups. Students were divided into teams of 2 or 3 (as they had been partnered for the project work) and were assigned to breakout rooms (there were observed students in 5 rooms for group C, 4 rooms for group B and 3 rooms for group A). The online delivery of the module limited the observation to the students in a breakout room, it was not possible to observe them all at the same time. The duration of each session was between 1h 45 minutes and 1h and 50 minutes and it permitted 3 visits to each breakout room. The session started with a brief presentation of the participant information leaflet and consent form 1 and students were asked to read them and to communicate their agreement in an MS Form. 16 students responded positively and later on, after clarifying some issues related to the consent form, 4 others confirmed verbally their participation. 1 student decided not to participate.

3.5.3. Questionnaire Design

Questionnaires are widely used tools for collecting data because they capture data from various types of questions (e.g. multiple-choice, closed questions, test scores, Likert items to measure attitudes), generate numerical data which can be analysed statistically, gather standardised information and can provide descriptive, inferential and explanatory information (Cohen et al., 2018). The disadvantage is that they take time to develop, pilot and refine, as it is an iterative process (Schweighofer et al., 2019). Quantitative data offered by questionnaires complement well other qualitative data and can increase the validity and reliability of the research (Punch & Oancea, 2014).

The design of the questionnaire was an iterative process. The initial draft included 12 questions organised, as suggested by other studies (Schweighofer et al., 2019; Patel et al., 2018; Visser-Wijnveen et al., 2016), in sections, along the three themes identified in section 2.3 – behavioural, emotional and cognitive engagement. After numerous cycles of refinement, an online form of the questionnaire was created using MS Forms and a small pilot study was conducted (see section 3.5.6) in which student feedback was solicited. The final instrument (see Appendix 5) contains 17 questions

organised in three main sections to capture students' view on the three domains of student engagement: behavioural, emotional and cognitive, based on the indicators chosen in section 2.3. Table 6 is mapping some of the questions against the engagement indicators determined in section 2.3.

Table 6. Examples of Questions that Show Student Engagement along the Three Themes

Student engagement theme	Section in questionnaire	Indicator example	Question example
Behavioural	**Participation and interaction**	Participation in class	During the class dedicated to the work on the project: (Tick as many as appropriate) □ I got actively involved in the data analysis process □ I listened to the lecturer's explanations and comments and applied them □ I asked questions □ I answered when the lecturer asked a question and I knew the answer □ I asked for help when I needed it □ I helped my colleagues when they needed help □ I didn't get much work done
Emotional	**Perception**	Sense of belonging	How would you rate the following statement? (Strongly agree, Agree, Neither agree nor disagree, Disagree, Strongly disagree) □ I enjoyed the collaboration with my project partner □ I felt supported by my peers and lecturer while working on the project □ I felt part of a learning community
Cognitive	**Knowledge**	Knowledge	The work on the project helped me: □ Understand when to apply regression analysis to a real-world problem □ Carry out successfully a regression analysis □ Make decisions or recommend measures based on root cause analysis

The section titles were changed (participation and interaction, perception, and knowledge – see Table 6) for understanding and accessibility purposes, and an additional section was used for categorisation purposes (gender, age group) at the beginning. The questionnaire includes three types of questions: (1) statements that use a Likert scale response, which permit a quantitative analysis of the participants' attitudes towards PBL; (2) open-ended questions to capture more depth and richness of responses, which are valid attributes of qualitative data (Cohen, et al., 2018); and

(3) multiple-choice questions, free choice ('tick as many as appropriate'), to capture various aspects of engagement along a particular dimension.

The questionnaire was internet-based. A week after the session dedicated to project work, at the beginning of class, the participants were asked to spend five to ten minutes to fill out the questionnaire. They were directed again to the consent form in case there were students who wanted to participate only to this part of the study or missed the previous class, and were guided through the questions and explained the rationale for qualitative questions. 22 students agreed to participate. The average time to complete the questionnaire was 6 minutes 36 seconds. The use of MS Forms preserves the anonymity of respondents, which was considered an important feature by the author, considering her dual role of researcher and lecturer (see section 3.6 on research ethics).

3.5.4. Interview Design

Interview is the dominant tool for data collection in qualitative research methods (Punch & Oancea, 2014). It provides rich communication as it uses various channels for communication – verbal, non-verbal, body-language, written (if online interviews are used) – and it should be a positive and enriching experiences for all participants (Cohen et al., 2018). Interviews explore the issues under study in more depth than a questionnaire. They offer the interviewer the possibility to discuss and understand the interviewee's point of view and their own interpretation and construction of the reality (Cohen et al., 2018), which aligns well with the interpretivist approach of this research. As suggested by literature, interviews can be used to produce further explanatory insights into the questionnaire data (Cohen et al., 2018). Although interviewing is time-consuming, cannot provide anonymity and is prone to interviewer bias, the advantages prevail over its disadvantages (Cohen et al., 2018). Interviews vary in terms of purpose, form, practicality of the situation and they have been classified into various categories, which are discussed in detail by Cohen et al. (2018), and Punch and Oancea (2014). No matter what typology is used, one of the most important dimensions of that variation is the degree of structure of the interview, which is closely linked to its depth (Punch & Oancea, 2014). Somewhere along the continuum from structured to unstructured interviews is the mixed approach – the semi-structured

interview, also known as focused interview, depth interview or qualitative interview (Adams, 2015). The semi-structured interview employs a combination of closed- and open-ended questions which gives the researcher some flexibility to diverge and pursue a response in more detail in order to get a better understanding of the interviewee's perceptions and meanings.

The semi-structured interview was selected for this research as it complements the questionnaire, offering more richness and adding depth to the study. The interview was designed according to the guidelines presented in Adams (2015), Cohen et al. (2018), and Punch and Oancea (2014). The target was 3 to 5 interviewees, although there are mixed opinions regarding the optimum number of participants. Some researchers suggest 11-12 people (Guest et al., 2006), others propose less than 20 (Crouch & McKenzie, 2006), whilst others consider that a researcher should interview as many people as necessary in order to gather the information they seek (Cohen et al., 2018). Due to time constraints and to the small size of the group under study, it was considered that a small number of interviews would capture well the various opinions regarding the student experience and engagement with material whilst using PBL for teaching. Therefore, 5 students were invited to the interview via an informal email (see Appendix 6). The sampling method used for the selection of the participants was purposive sampling (Edgar & Manz, 2017; Galloway, 2005), which is accepted, even recommended in case study research, according to Merriam (1998) cited by Yazan (2015). The choice of sampling method was guided by research (during observation the researcher noticed that some students were uncomfortable in the online space) and relied on the researcher's professional judgement, having a working relationship with the students. All 5 students agreed to participate, and interviews were scheduled the week after the delivery of the questionnaire, outside of class time. They were carried out via Microsoft Teams, the restrictions due to COVID-19 limiting drastically the face-to-face activities on site. Prior to interview, the participants were asked to read the Consent Form 2 (see Appendix 7) and they were asked their consent at the start of the interview. The participants were informed about the approximative duration of the interview (around 30 minutes) and were asked permission to be recorded, as the use of transcripts ease the data analysis significantly. All participants

agreed. The duration of the interviews was on average 30 minutes, except one which lasted approximately 44 minutes due to connectivity issues.

The interviews addressed the same themes as the questionnaire – behavioural engagement, emotional engagement and cognitive engagement. They included a mix of closed- and open-ended questions and made use of prompts and probes (Cohen et al., 2018) – see Appendix 8. The main aim was to understand the participants' experience with PBL and how they perceive engagement and to gather as many points of view as possible. The final design of the interview was done after the analysis of the questionnaire as students were presented the findings and were asked to elaborate on various aspects along the engagement themes. There are several ethical issues related to interviews, especially related to the dual role of the researcher (researcher-lecturer). These aspects will be further explored in section 3.6.

3.5.5. Validity and Reliability

Ensuring validity in mixed methods is challenging as this type of research method is at the intersection between qualitative and quantitative methods. Some researchers even claim that the term 'validity' should be replaced by 'legitimation' (Onwuegbuzie & Johnson, 2006), whilst others argue that validity should go beyond design, procedures and techniques to include fundamental issues in epistemology and ontology (Long, 2015). Yin's approach to validity and reliability in case studies (Yin, 2009) has been embraced by many researchers because, although of positivist origin, it also includes elements of interpretivism such as triangulation, discipline and protocols (Yazan, 2015). This research addressed both validity and reliability.

Internal validity refers to the accurateness of the data collection tools, procedures and techniques, which ensures credibility and authenticity of the data (Cohen et al., 2018). Using triangulation of multiple sources of evidence (Yin, 2009) ensured that the construct measured what it needed to measure. The data collection tools were designed in such a manner (see sections 3.5.2, 3.5.3 and 3.5.4) so that they could offer not only a comprehensive and accurate description of the case, but also the right interpretation, as interpretivists suggest (Yazan, 2015 citing Stake, 1995). It has been recognised that generalisability (or external validity) is not straightforward in a case study research (Punch & Oancea, 2014). However, building an in-depth understanding

of the impact of PBL on student engagement in a particular engineering module is worthwhile as what is learned from this study may be transferable to wider GMIT engineering context, although it might not apply to another institute or another context.

Reliability refers to the repeatability of the study and is a concern particularly in studies where a single researcher is involved because reliability issues are closely related to subjectivity (Babbie, 2010). This research used protocols and procedures for data collection (see sections 3.5.2, 3.5.3 and 3.5.4) and a clear methodology for data analysis (see section 4.2), documented all aspects of the research and kept careful documentary evidence, thus achieving consistent and trustworthy results (Yin, 2009). In order to increase the reliability of the study, an inter-rater reliability check based on Cohen's kappa coefficient (McHugh, 2012; Warrens, 2014) was performed. Although it is acknowledged in literature that the kappa coefficient has its limitations (Warrens, 2014; Warrens, 2015; McHugh, 2012), the researcher decided to use it for this study because it has been used in numerous qualitative studies, it is generally thought to be a robust measure as it accounts for chance agreement and it has several useful interpretations (Warrens, 2015) – see section 5.3.

3.5.6. Pilot Study

The term pilot study can refer to a feasibility study or to the pre-testing of a particular data collection instrument (van Teijlingen & Hundley, 2001). The latter applies to this research as the pilot study was used to collect feedback on the data collection tools and, based on this feedback, to make adjustments and refine the tools before attempting the final study. There are various opinions about piloting, both for and against – see Ismail et al. (2018) for a compilation of various scholars' views. The author took De Vaus's advice cited by Ismail et al. (2018): 'Do not take the risk. Pilot test first', especially when the researcher is a novice in the use of the tools.

Before piloting, the three data collection tools (observation, questionnaire and interview) went through several iterations. Experts in the supervisory team reviewed them for clarity and readability of questions, suitability of the type of questions and their alignment with the research question, omissions, redundant questions, layout, appropriateness and possibly offensive or intruding questions.

A pilot study was carried out on the observation tool and the questionnaire design during week 10. The observation was piloted with the students in group B (all present, except one, had agreed to participate), and it took 30 minutes. One finding from the pilot was that very good preparation and organisation in advance is necessary. All communication was done via MS Teams and some delays were encountered because certain settings were not done in advance or links had to be retrieved on the spot. Another finding was related to the design of the observation sheet. It had to be re-designed to permit faster note taking during observation.

The questionnaire was tested by two students in Group C, as literature suggests that a pilot study sample should be 10% of the sample size planned for the final study (Conneely, 2008). The only criterion of participants selection was the ease to access (convenience sampling). The two students were 10 minutes earlier for class and they accepted to review the questionnaire. They were given a form and asked to give feedback on the following aspects: clarity of instructions, content, structure, logic of the questions, technical issues when using the online form, time to complete and other suggestions. Both students agreed that instructions were clear and questions were meaningful. They requested to remove ‘Joy’ from the question that asked how they felt when working on the project and to add ‘lack of interest’. Another suggestion was to add ‘Keeping up to date with work instead of letting it pile up until the end of the semester’ to the question that asked how PBL helped them. The also advised on using branching in order to link some answers to following questions.

An interesting finding was students did not want to engage with the qualitative open-ended questions. That explained why it took less than 5 minutes to fill out the questionnaire, when the estimated time was 10 minutes. After discussions with the supervisor, it was agreed on a different strategy for the final study: guide students through the questions and ask them to explain their choices when completing the questionnaire. As a result, the majority of the participants answered the qualitative questions.

3.6. RESEARCH ETHICS

Ethics refers to a multitude of considerations related to right and wrong, as (Velasquez et al., 2010) define it: 'ethics is based on well-founded standards of right and wrong that prescribe what humans ought to do, usually in terms of rights, obligations, benefits to society, fairness, or specific virtues'. In research, ethical issues arise in all phases of the research, from the choice of topic to data analysis and publications, and educational researchers must be aware of the ethical implications of any decisions they make at any stage of their research (Punch & Oancea, 2014).

This research was carried out in accordance with GMIT research ethics policy, GDPR and the requirements of the GMIT MA in Teaching & Learning Research Ethics Committee. The committee approved the research ethics proposal document, which included the documentation critical to the primary research: Participant Information Leaflet and Informed Consent Forms (see Appendices 2, 3 and 7). The key elements of the documentation were based on six principles set out by Hammersley and Traianou (2012) and embraced by many other scholars: the minimisation of harm, respect for the autonomy or freedom of the participants to the study, privacy, trust, reciprocity and equity. The main ethical considerations deriving from these principles, which are applied in this research, are briefly discussed below.

3.6.1. MINIMISING HARM

Hammersley and Traianou (2012) state that all research involves the risk of harm, as harm is not necessarily physical. This research is not of sensitive nature, but the welfare of the participants to the study is of paramount importance and it was kept in mind all the time, the researcher ensured that no psychological or emotional damage was done to the students and the research had no consequences to the project work in which the participants were involved. Consideration was given to the use of class-time to carry-out this research and informed consent and privacy through anonymised data was used to avoid harming the participants to the study.

3.6.2. Informed consent

Informed consent is key in research ethics (Ramrathan et al., 2017). No coercion was used to force students into taking part in the research, they voluntarily signed the Informed Consent Forms. Information about the nature of the study, about the location where it would take place, how much time it would take and what was required from the participants were communicated in advance to all potential participants using the Participant Information Leaflet. There was no penalty if the students did not want to participate. As this research is linked to teaching, students were assured that their teaching and assessment experience would not be affected whether or not they decided to take part in this research study.

3.6.3. Confidentiality and Anonymity

According to data security and dissemination ethical principles (Ramrathanet al., 2017), participants' information was kept confidential. Although the researcher knows who provided the information (e.g. some students were interviewed), it was not disclosed in any way that could identify that individual, thereby protecting their privacy. Data collected/files was securely stored on the researcher's passworded computer, according to GMIT security and data protection rules.

3.6.4. Benefits to participants

Incentives, other than payments, for participation in the research study (Cohen et al., 2018) were considered. For example, participants to interviews were offered a digital badge (see Appendix 9). The participants gained other types of benefits as well, such as the opportunity to improve their learning experience, the opportunity to reflect on their learning, increased self-esteem, increased self-awareness, satisfaction in having created valuable knowledge and contributing to science, a greater personal understanding of the research area under observation, enjoyment and sense of belonging and empowerment.

3.6.5. Power and position

Often the researcher can be seen in an asymmetric position of power with regard to the participants (Cohen et al., 2018; Ramrathan et al., 2017) which is the case in this

study, the researcher being the lecturer at the same time. The researcher tried to reduce the power differentials, by enabling participants to have some power over decision-making in the research (e.g. when to organise interviews, duration of the activities), starting the study with some explanations and short activities to put participants at ease and explaining that it was a research study, not an assessment, explaining clearly that the participation to the study is voluntary and there would be no penalty if a student did not want to participate or felt uncomfortable. The researcher ensured at all times that the study did not affect in any way the teaching and learning process. In order to make up for the class time used for research, which amounted to 15 to 20 minutes, the lecturer made herself available at the end of the last session of the semester for questions and answers related to the 3rd project.

3.7. CONCLUSION

The aim of this chapter was to construct a research methodological framework. This way, the research could be positioned in a research paradigm, which would inform the selection of the data collection method with a view to achieve objective 4. Three dominant research paradigms in educational research were investigated in section 3.3: positivism, interpretivism and pragmatism. The interpretivist approach, with elements from pragmatism and positivism, was found the most suitable for the aim of this research, which seeks to understand the participants' interpretation of their attitude and experience with PBL and how they see its impact on their engagement with the module. Section 3.4 analysed the research methodologies that could support the research objectives. Locating the research in the interpretivist paradigm with positivist and pragmatist influences and considering the research question and the research type determined the choice of methodology, the case study.

Section 3.5 showed that mixed methods for data collection can support the pragmatic approach to research and enable multiple sources of evidence for an in-depth and broad investigation. The choice of mixed data collection methods, in line with the methodology selected, completed the research methodological framework. The data collection tools include observation, questionnaire and interview, which are mixed methods, but predominantly qualitative. The design of the three instruments and the

importance of piloting them was also discussed in this section. Special attention was given to ethical considerations when conducting the study, discussed in section 3.6.

To summarise, this chapter identified the most appropriate methodological approach for the research, in line with the research question and the objectives of the study. The next chapter will discuss the findings of the research carried out within this framework.

4. CHAPTER FOUR: RESEARCH FINDINGS AND ANALYSIS

4.1. INTRODUCTION

This chapter presents the findings from the qualitative and quantitative data collected according to the methodology presented in Chapter 3. The findings seek to address the aim of the research, to evaluate the impact of PBL method on student engagement and, in particular, objective 4 – to evaluate the impact of PBL method on student engagement, as presented in Chapter 1. The chapter starts with an overview of the data analysis methods used in this study, followed by the findings presented thematically, according to the main themes of student engagement and corresponding indicators outlined in section 2.3 and in Table 4 in section 3.5. Section 4.3.1 presents the findings related to impact of PBL on behavioural engagement, section 4.3.2 presents the findings related to impact of PBL on emotional engagement and section 4.3.3 presents the findings related to impact of PBL on cognitive engagement. A deep analysis and discussion of these findings follow in Chapter 5.

4.2. DATA ANALYSIS METHODS

The study employed a mixed data collection method (see section 3.5), therefore both qualitative and quantitative evidence were analysed. The next two sections discuss the data analysis methodology for these two types of data. It will be seen that an interpretivist perspective was applied to data analysis, 'the process of making sense of the data' (Yazan, 2015; Merriam, 1998).

4.2.1. QUALITATIVE DATA ANALYSIS: THEMATIC ANALYSIS

The qualitative data analysis was a systematic process which followed a clear methodology as suggested by literature (Gagnon, 2010; Richards et al., 2019). Thematic analysis was used as it is considered a good approach to research seeking to understand people's views or experiences from a set of qualitative data such as interview transcripts or survey responses (Braun & Clarke, 2006). A deductive approach was employed, based on the themes for student engagement identified in literature (see section 2.3). Firstly, the interview transcripts were checked against the

video recording. Secondly, data were categorised and colour coded according to the themes identified in section 2.3. Different shades of each colour (for example, blue for behavioural engagement) were used for subthemes identified – see Table 7.

Table 7. Extract from Interview Analysis Table with Colour Coding for Subthemes

Theme 1: Behavioural engagement						
Participation in class		Learning effort		Communication		NEW! Barrier: online T&L
Theme 2: Emotional engagement						
Learning satisfaction		Learning passion		Sense of belonging		
Theme 3: Cognitive engagement						
Building knowledge		Perseverance		Self-regulation		
Other findings						
Class dedicated to project		Challenging		Structure of class		Forming the groups

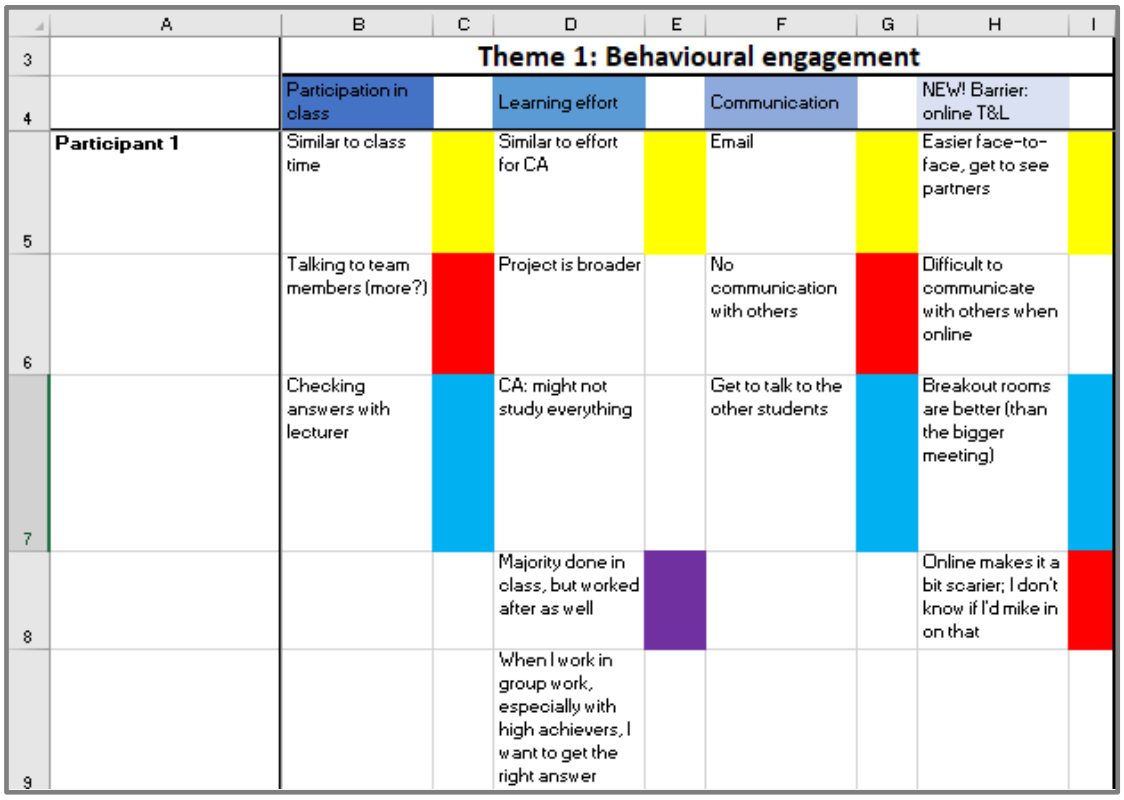
Text in the interview transcripts was highlighted according to the colour codes. The three dimensions of student behaviour (behavioural, emotional and cognitive) are interrelated, as mentioned in section 2.3, therefore sometimes a part of the text was highlighted using two or three colours – see a short extract in Figure 5 and the full transcript of one interview in Appendix 10.

In general, yeah, I would. I know it's grand to have it nice and easy, but you're not really learning unless you're getting challenged to solve it, so I think it's better. Yeah.

Figure 5. Extract from an Interview Transcript

The analysis of the data from interviews also involved the comparison of units of meaning across transcripts and colour coding the various ideas within each subtheme (see an example in Appendix 11). Colour coding was also used for the qualitative data from questionnaires. Key words or expressions were colour coded and frequency tables were created.

The last step of the methodology was the actual analysis of the coded data, which involved a systematic organisation, structuring and integration of the data. Oun and Bach (2014) cite Gaskin (1994) on the idea that many interpretivist researchers find it useful, even necessary, to structure qualitative data, which becomes a form of quantitative data. This can result in visual or graphical representations (see an example in Figure 6, Appendix 11 and Appendix 13), which are considered important in qualitative data analysis (Verdinelli & Scagnoli, 2013), and which help understand and explain human action (Oun & Bach, 2014). As a result of the analysis, subthemes were reviewed and, sometimes, renamed or combined or even discarded.



	A	B	C	D	E	F	G	H	I
3		**Theme 1: Behavioural engagement**							
4		Participation in class		Learning effort		Communication		NEW! Barrier: online T&L	
5	**Participant 1**	Similar to class time		Similar to effort for CA		Email		Easier face-to-face, get to see partners	
6		Talking to team members (more?)		Project is broader		No communication with others		Difficult to communicate with others when online	
7		Checking answers with lecturer		CA: might not study everything		Get to talk to the other students		Breakout rooms are better (than the bigger meeting)	
8				Majority done in class, but worked after as well				Online makes it a bit scarier; I don't know if I'd mike in on that	
9				When I work in group work, especially with high achievers, I want to get the right answer					

Figure 6. Sample of visual representation of data (colour coding within subtheme)

There are computer applications that can be used either for coding and classification only, such as Otter (https://otter.ai), or for the whole data analysis, such as Quirkos (https://www.quirkos.com) or NVivo. The author chose to do all the analyses manually for a couple of reasons: (1) it was not an excessive amount of data and the time frame for the study would not permit to become proficient in new software, and (2) literature warns that data analysis software packages should be used with caution as complexity

of the data may be lost or the quality of the analysis may decrease (Oun & Bach, 2014; Gagnon, 2010). The following section will discuss the quantitative data analysis methodology.

4.2.2. Quantitative Data Analysis

Quantitative data analysis is well documented (Richards et al., 2019; Bryman & Cramer, 2011) and usually includes complex analyses such as correlation or multivariate analysis. This study is interpretive by nature as it seeks to understand the impact of PBL on student engagement using their views on the engagement, therefore there was no need for complex analyses or software package.

Data from questionnaire were collected via MS Forms, which offer the advantage of automatic creation of visual representations, consequently there was no need for additional analysis. For the data collected during observation, a mix of letters, numbers and symbols was used for coding (see an extract from an observation sheet in Table 8 and a screenshot of an entire observation sheet from Excel in Appendix 11). Using the coding for observation data, frequency tables and charts were created to illustrate student engagement along the subthemes that emerged from the analysis (see an example in Appendix 13). The analysis was complemented by the researcher's notes taken immediately after the observation.

The quantitative and qualitative findings from the analysis of the data collected with the three methods – observation, questionnaire and interview – are summarised in the next section.

Table 8. Extract from Observation Sheet with Coding

Observation domain	Observation focus	Incidence			Comments	Indicator
		Room 5 (one participant from another team)				
		Participant 1	Participant 2	Participant 3		
Behavioural engagement	Student has already started working on the project before class (Y, N)	N	N	Y		learning effort learning satisfaction
	Student discusses project-related issue with a peer (V, C, E, S, O)	V, V, V	V, V, V	V, V, V		communication feeling of being supported sense of belonging
	Student collaborates with another peer (from a different team) (V, C, E, S, O)	V, V, V	V, V, V	V, V, V		communication feeling of being supported sense of belonging
	Student asks a question (L, S)	S, L, L		L, L, L		participation in class feeling of being supported learning passion learning satisfaction
	Student answers a question (L, S)	N, L, N		N, L, N		participation in class communication sense of belonging
	Student discusses other topics, not related to the project (☑)					communication learning satisfaction learning passion

Coding: Y = yes, N = no

V = verbal; C = chat box; E = email; S = screen sharing; O = other (specify in comments - could be Google docs or something else)

L = lecturer; S = student

On a scale of 1 to 5, 1 = not at all; 2 = very little; 3 = a little; 4 = a lot; 5 = a very great deal

+ is positive emotion, - is negative emotion

☑ = Occurrence

4.3. RESEARCH FINDINGS

The research findings are organised along the impact of PBL on the three main student engagement themes identified in literature (see section 2.3): behavioural engagement, emotional engagement and cognitive engagement. For each theme, the findings are subdivided into (1) findings from observation; (2) findings from questionnaire and (3) findings from interviews. Quantitative findings from questionnaire and frequencies from structured qualitative data are complemented by qualitative findings which provide insights and observations that are further used to support the discussion of the findings in Chapter 5. The findings from all three groups are merged together as the sample sizes are small and this was not a comparative study.

4.3.1. FINDINGS RELATED TO THE IMPACT OF PBL ON BEHAVIOURAL ENGAGEMENT

This section presents the findings related to the impact PBL has on behavioural engagement. Indicators of positive and negative behaviour engagement were considered, including learning effort, participation in class and communication, as outlined in section 2.3 and in Table 4 in section 3.5.

4.3.1.1. Findings from Observation

One key indicator of behavioural engagement is the amount of effort students put into the project. Observing what students were doing during the first visit to the breakout rooms or simply asking them, it was found that a low proportion of the participants (35%) had started working on the project prior to the class dedicated to project work, as can be seen in Figure 7. Based on observation of students' behaviour in class, they all made good use of the session and put good effort into the work.

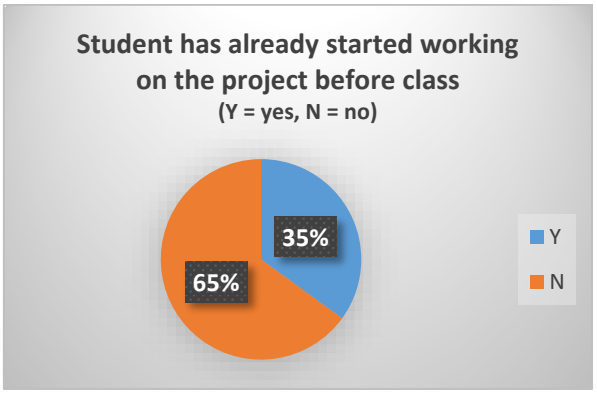


Figure 7. Proportion of Students Who Had Started Working on Project Prior to Class

Another important indicator of behavioural engagement is participation in class. A high number of students participated actively during the project session. 19 out of the 20 observed participants (95%) were discussing the project when the researcher joined their breakout room for the first time. There was only one participant who was discussing another topic with his project partner. The observation notes mention that he had problems with his computer and was trying to solve them. As Figure 8 indicates, less students were discussing the project in subsequent visits. The researcher had noted that when there was no discussion, typing could be heard. The number of students discussing other topics increased over the following visits to 3 during the second visit and 2 during the third visit.

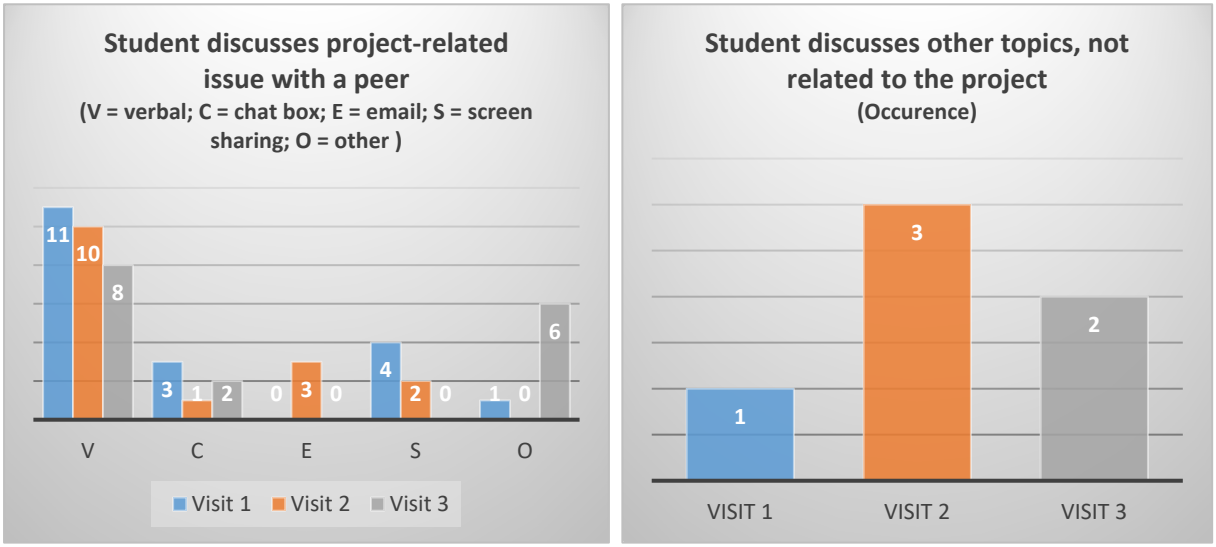


Figure 8. Number of Students Discussing Project (Left) or Other Topic (Right) in Class

The observation notes indicate that groups had different dynamics. There was more interaction between participants who were project partners, whilst the participants who were from different partnerships interacted less. There was only one very quiet partnership, but the researcher had noticed some activity, either screen sharing or typing.

Other factors that suggested participation in the project-work class were asking and answering questions. Figure 9 shows that all questions except one were addressed to

the lecturer. The incidence was nearly the same over the three visits, both in terms of questions asked (9 in the first visit, 10 in the second visit and 9 in the third visit) and answered (5 in the first visit, 4 in the second visit and 4 in the third visit). The observation notes show two main trends in relation to interaction with the lecturer: (1) partners were still discussing the project and did not have any questions during the first visit, but then needed clarifications or help during the second visit; (2) partners wanted to clarify some aspects of the project from the very start and then, when lecturer visited them the second time, they were absorbed in their work, did not have any questions. Another aspect revealed by the observation notes was the fact that each breakout room had a 'designated spokesperson' in the sense that the same person in the room would ask questions each time, with the exception of 3 rooms (out of 12), where both partners asked questions.

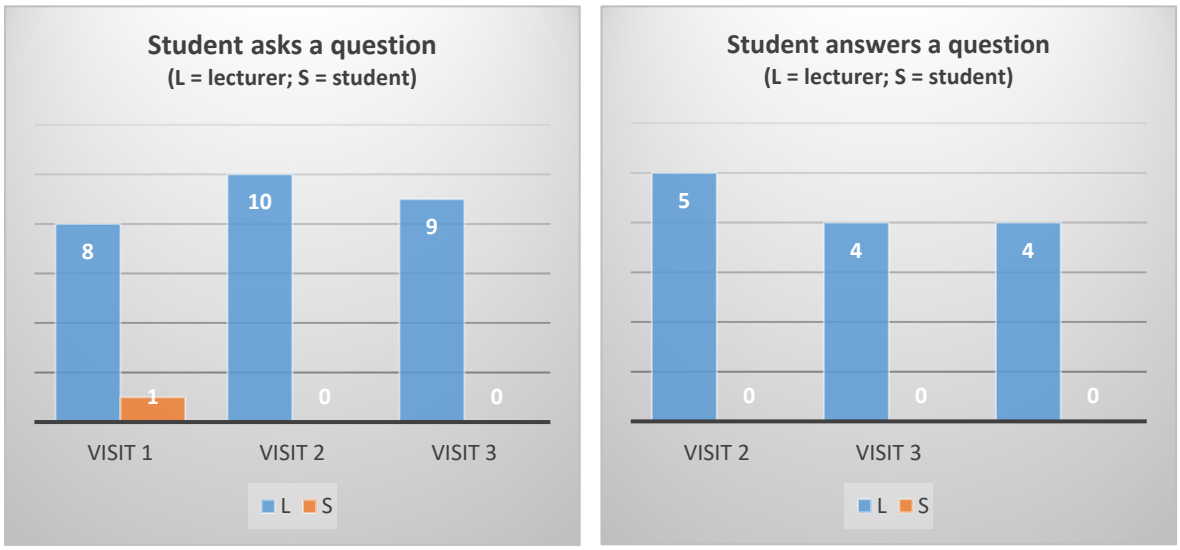


Figure 9. Incidences of Student Asking (Left) or Answering (Right) Questions

Another indicator of behavioural engagement is communication. Figure 8 shows that most of the communication was verbal (29 incidences out of 51), but some participants preferred the chat box on MS Teams (6 incidences out of 51), email (3 incidences out of 51) or other means. The researcher noted that the participants who were discussing via MS Teams chat box did not have a microphone, whilst the other methods (O) used for communication in class, which appeared 7 times, were students' own messaging tool or MS Teams chat. There were 6 instances of screen sharing between the participants in the breakout room. Very little collaboration with students outside the

partnership (7 incidences) was observed. That happened in the only two breakout rooms where students from different partnerships were assigned. The observation notes mention that, in each case, one student's partner missed the session and they had to join another partnership.

The next section presents the findings related to behavioural engagement from the questionnaire.

4.3.1.2. Findings from Questionnaire

The questionnaire (see Appendix 5) was distributed a week after the observation took place and students were instructed to read the participant information leaflet and the consent form again before filling out the questionnaire, in case they missed the previous session. As a consequence, only 22 out of 25 (88%) consented to participate to this stage of data collection (see Figure 10). It should be mentioned that MS Forms numbered the participants from 1 to 25, including the three students who did not consent.

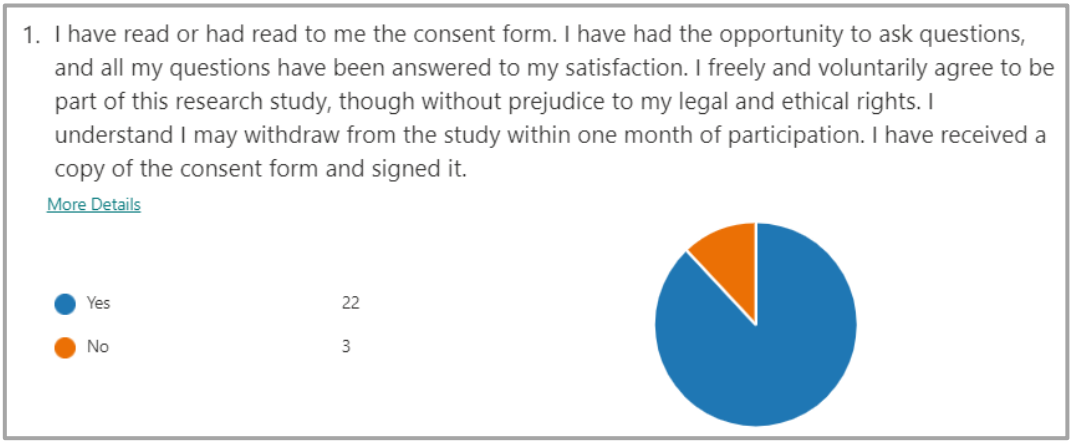


Figure 10. Number of Respondents Who Agreed to Fill Out the Questionnaire

The next three questions were asked in order to identify the profile of the respondents. All 22 participants were male, the vast majority belonging to one age category, 18 to 24 years old (21 out of 22). It should be noted that the two students who were involved in the piloting of the questionnaire did not participate.

In order to identify the amount of effort students had to put into the project, the participants were asked to evaluate their work on the project with respect to 7 aspects

relating to such areas as support notes, previous knowledge, feedback or workload, as illustrated in Figure 11. The majority of participants agreed or strongly agreed that they had enough support (90.9%) and enough knowledge (63.6%) to attempt the project before class. However, the responses to the last question suggest that a lot of work was done in class (68.1%). That supports the findings from observation related to the active participation in class. Only a small proportion (36.3%) of the participants agreed or strongly agreed that they used the session dedicated to project to get guidance and feedback from the lecturer; the majority (54.5%) neither agreed, not disagreed. At the same time, the high percentage (50%) of participants who said they implemented the feedback immediately contradicts the previous response.

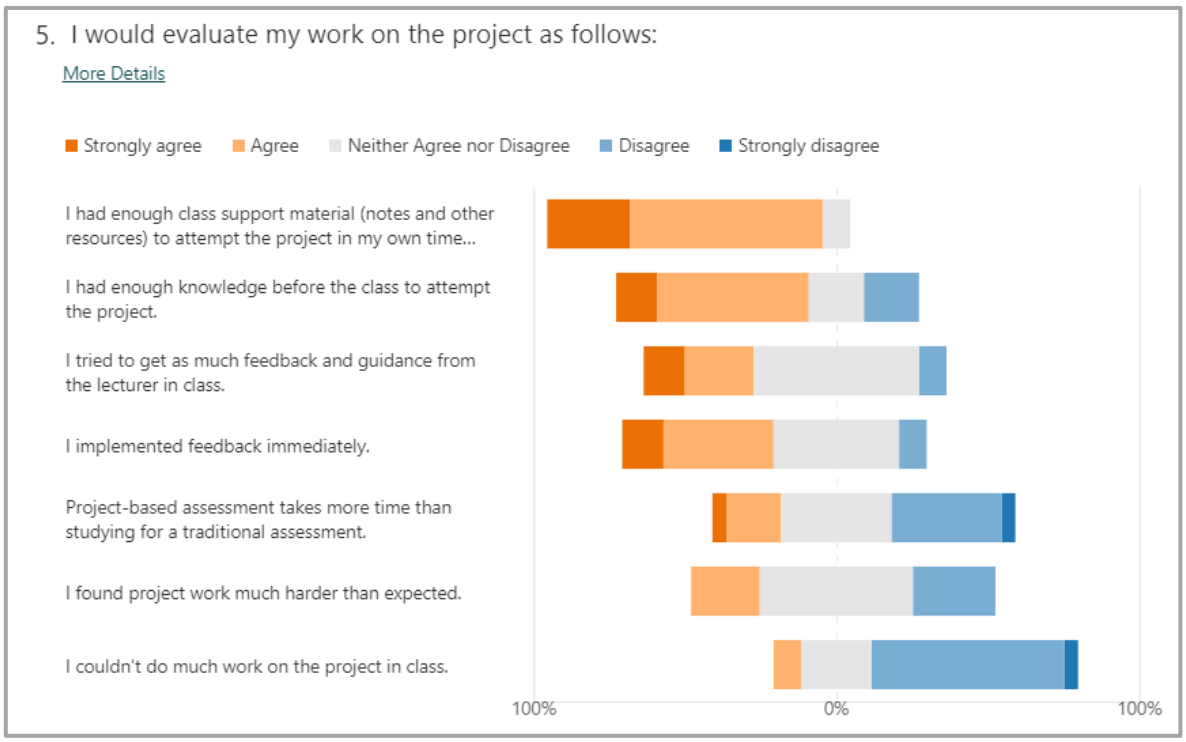


Figure 11. Responses to the Question Related to Evaluation of Effort

As it is difficult to measure and evaluate the effort students put into project work, the participants were asked to compare the amount of time they spend on it as opposed to time spent studying for a traditional assessment. There were mixed opinions. Only 22.7% agreed or strongly agreed that project-based learning takes more time than studying for a written assessment, 40.9% disagreed or strongly disagreed, while 36.4% neither agreed nor disagreed. Another inconclusive response was related to

how hard the project was. A relatively low proportion (22.7%) of respondents agreed that the project was harder than expected, while 27.3% disagreed. The rest (50%) were not sure, neither agreed not disagreed.

The answers to question 6 (see Figure 12) suggest a good participation of students in project class, in line with the findings from observation. The most common response was 'I listened to the lecturer's explanations' (20 out of 22 or 91%), but other responses show an active participation: 13 out of 22 (59%) got actively involved in data analysis, 14 out of 22 (64%) asked for help and 13 out of 22 (59%) helped their colleagues. Only 2 respondents said they did not get much work done.

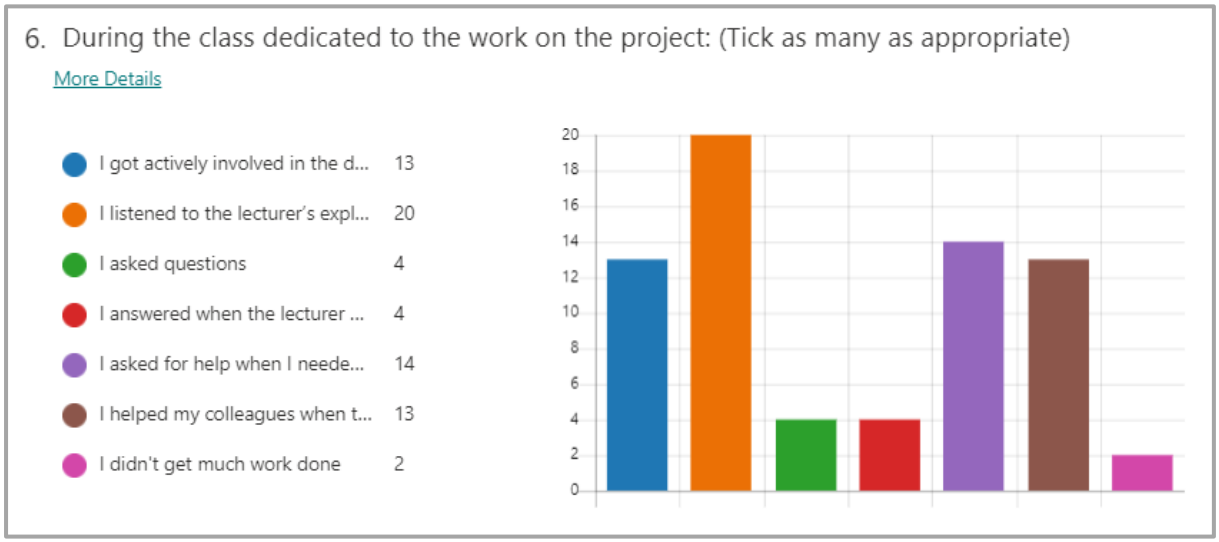


Figure 12. Responses to the Question Regarding Student Participation in Class

The answers to question 7 offered some insights into the rationale behind the participants choices in question 6. Only one of the 2 students who answered 'I didn't get much work' gave explanations: "Difficulty working with classmate". An idea that appeared 7 times (out of 15 explanations) was that students liked to get actively involved in the work and to have the opportunity to ask for help when necessary, as described by:

> Participant 21: I like to get the work done in class so if I got stuck the lecturer could help me.

Another idea that appeared 3 times in the participants' responses was related to collaboration with peers. For example, one participant mentioned:

> Participant 4: When fellow students were unsure of their work, we communicated to see if we had both done the problem in similar ways.

In relation to the collaboration in class, 3 participants said that breakout rooms helped them. To quote a participant:

> Participant 25: I was in a breakout room with 2 others and if they needed any help or if I needed help, we could ask each other.

As communication with peers was observed in class and more details were obtained during the interviews, students were only asked about their best way to communicate with the lecturer. Figure 13 shows that Teams chat is the preferred communication channel (33%), followed equally by email and feedback to work submitted (28% each). Only 13% preferred face-to-face discussions and nobody chose 'posts on Moodle'.

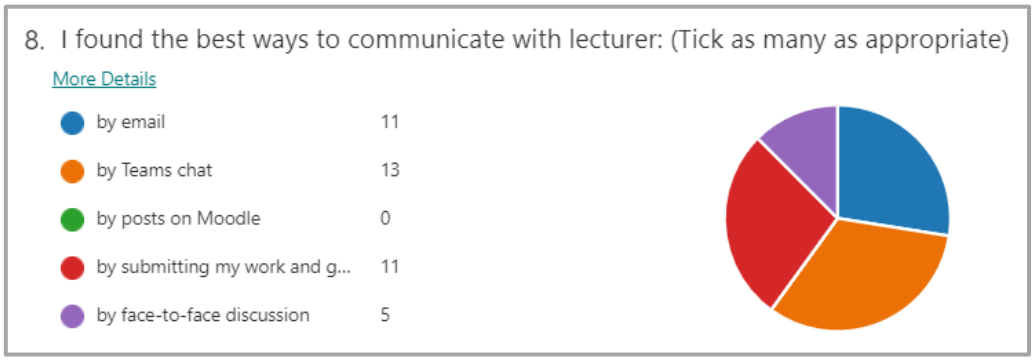


Figure 13. Responses in Relation to Preferred Ways to Communicate with Lecturer

The findings from interviews for the behavioural engagement theme are presented next.

4.3.1.3. Findings from Interviews

In terms of learning effort, the findings from the interview supplemented the findings from the other analyses. Participants were asked if they worked on the project out of class hours and how much effort they put into project work in comparison with study effort for a traditional written assessment. 4 out of the 5 interviewees mentioned that they worked after class in order to finalise the project and submit on time. The fifth

participant did not specifically say it, but from the discussion it was clear that he did work after class.

The findings regarding the comparison effort put into project work versus study for a traditional assessment showed mixed opinions. There was no clear majority, similar to the findings from the questionnaire. Participant 1 didn't see any difference, participants 2 and 4 thought they put more effort into the project, whilst the other two participants thought they usually study more for a written assessment. However, the interviews shed some light on the reasons why students feel they put more or less effort into project work than study for a written assessment. For example, participant 2 felt he put more effort into project work because "it's more of an ongoing thing" and "I had to actually work", while participant 5 considered he put less effort into the project, although at a second thought: "Maybe for project you don't feel like you're doing too much although you are", which matches participant 4's characterisation of the project work as "less stressful". Both participants who said they put more effort into studying for a written assessment gave similar reasons for their judgement:

> Participant 3: Well, I'd say I would probably put more effort into the assessment studying 'cause I have to remember everything, and for the project is just to look at stuff… then use the information and then that's kind of done, out of the way…
>
> Participant 5: …if I'm studying for an assessment it kind of makes it more broader 'cause you don't really know exactly what's gonna come up so you have to cover a lot more, where projects would be, you know, specifically in what area you're covering and what exactly you need.

An unexpected comment of one interviewee linked the amount of effort put into study for either project or traditional assessment to the allocated grades:

> Participant 5: I'd say it depends probably on… what kind of percentage it's worth. If it's worth a lot, then obviously you'd put in more work if you feel like it's worth the time.

In relation to participation in class, the findings from the interview correlate with the findings from observation and questionnaire. Four participants mentioned the discussions with their peers in the breakout rooms, 3 mentioned the clarifications with the lecturer during the visits to the breakout rooms. 3 out of the 5 participants didn't think there was much difference between their general participation in class during the session dedicated to the project, but two of them found it different. Participant 3

considered she did more work than usual, while participant 4 felt he might have spent some time not doing any work, but rather trying to understand what needs to be done and how to split the work between the partners.

In terms of communication in class, all interviewees agreed they discussed and shared screens in the breakout rooms, which support the findings from observation and questionnaire. Furthermore, all participants indicated very little or no collaboration at all with other peers outside their partnership. Additional information was found in relation to the means of communication outside class. Each participant indicated they used a different tool: email, MS Office, phone messaging, OneDrive, MS Teams, MS Teams' chat.

The analysis of data from interviews identified a new factor that influenced students' behavioural engagement: the transition to online teaching and learning. The online delivery of all modules was imposed to students due to the COVID-19 pandemic and, as it was not students' choice, it has affected their behaviour in and outside class. All five participants indicated they felt uncomfortable online when they were in big groups (the largest group has 15 students), but they found the breakout rooms helpful. Participant 1 called the online experience "scarier", participant 3 said "shy", participant 4 referred to it as "awkward" and participant 5 mentioned "intimidating". One participant tried to explain:

> Participant 2: It could be… not daunting with everybody in the group, but a little bit harder to ask questions. Yes, that's all. That's how we feel about that… I'm not sure, to be honest. It's definitely just a mental thing. I don't know. …with a question to ask I would have no problem asking, maybe just not 100% confidence in answering.

All participants considered it was easier to work on site, face-to-face, as mentioned by:

> Participant 5: To be honest, I myself think it's all better in college, not online. Because you're in front of a person, you can kind of read their feelings… and people are more inclined to talk and engage in person rather than online. But then, again, this is all new to everyone, so people are probably not used to it.

Overall, the findings from the analysis show a positive impact of PBL on students' behavioural engagement. An unexpected finding in relation to online learning has

emerged from the analysis. Next, the findings for the theme of emotional engagement are presented.

4.3.2. Findings Related to the Impact of PBL on Emotional Engagement

This section presents the findings related to the impact PBL has on emotional engagement. Indicators of positive and negative emotional engagement were considered, including learning satisfaction, feeling of being supported, sense of belonging and learning passion as outlined in section 2.3 and in Table 4 in section 3.5.

4.3.2.1. Findings from Observation

The observation took place online, therefore the focus was on sound to capture indicators of emotional engagement. Although behavioural indicators showed that all students were actively involved in the project work, a very small number of incidences of energetic involvement in discussions or express of enjoyment were noticed (see Figure 14). During the first visit to the breakout rooms only 4 participants (20%) showed energetic involvement and only 1 (5%) seemed to express enjoyment. During the second visit the number increased to 6 (30%) participants who were energetically involved in the discussions and 2 (10%) who seemed to feel enjoyment, but during the third visit the incidence decreased again, with no student expressing enjoyment, as Figure 14 shows.

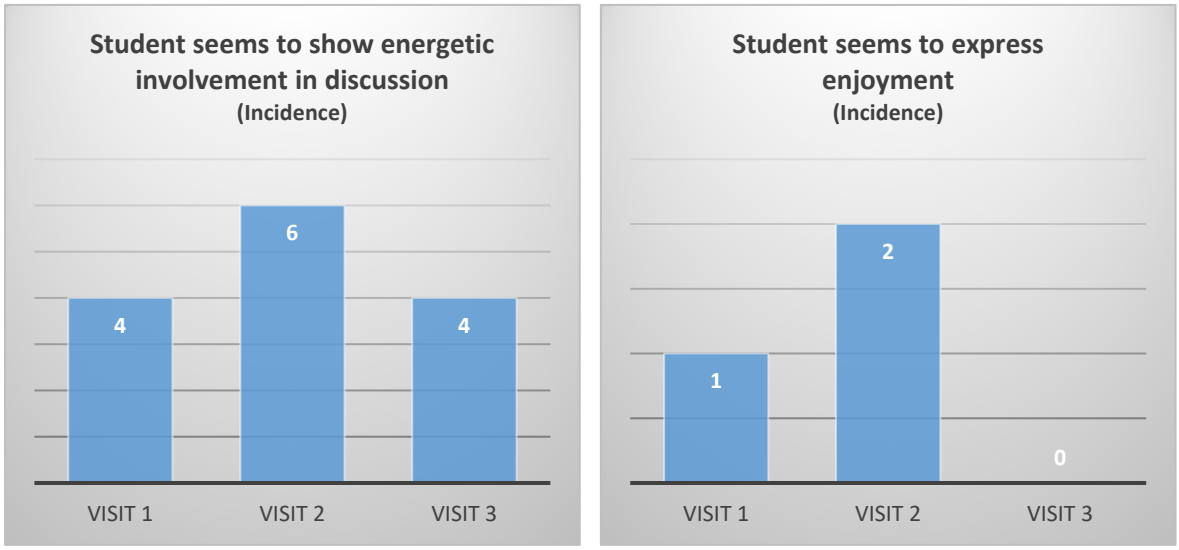


Figure 14. Incidence of Indicators of Energetic Speech (Left) and Enjoyment (Right)

These findings correlate with the findings from the observation of behavioural engagement. Students were discussing more at the beginning and less towards the end of the session when they were more involved in writing up the report.

Another indicator the researcher had under observation when visiting the rooms was long pauses. As Figure 15 shows, the number of long pauses recorded has increased with each visit. Originally, that was considered a sign of boredom. However, the observation notes inform that the communication in room 3, group C, was always done via chat box as one of the participants in the room did not have a microphone. All their communication was written and could be seen in the chat box. A similar situation was recorded for room 3, group B, the communication was seen in the chat box. In the other incidences the researcher could hear typing. The observation notes inform that most of the students seemed to have divided the work between themselves and once they clarified the analysis, they were each writing their own part.

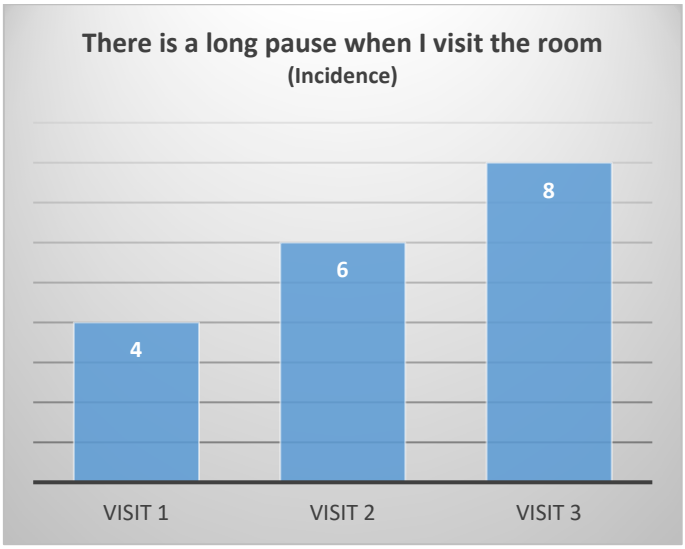


Figure 15. Incidences of Long Pauses

The chat box in each breakout room was monitored constantly for use of emoticons, which can suggest positive or negative emotion. MS Teams permits that even if the lecturer is not in the room. Participants who could communicate verbally did not use the chat box at all. Emoticons were used sparsely, as seen in Figure 16, and only by the students who could communicate only in writing. They all suggested positive emotions.

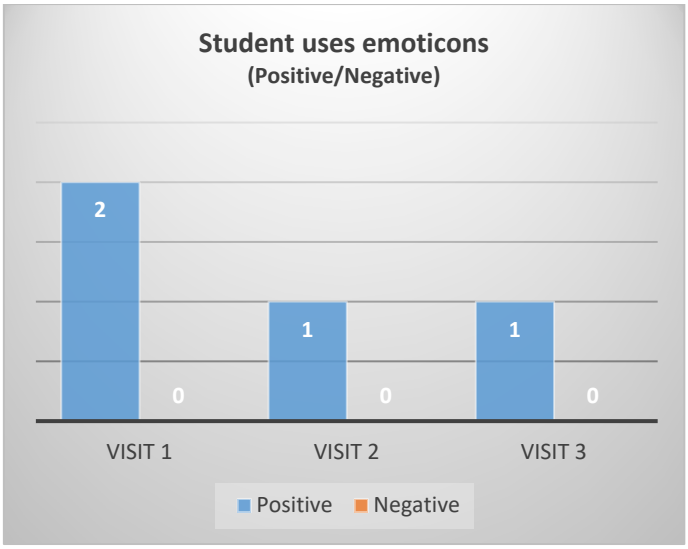


Figure 16. Incidences of Use of Emoticons

The next section discusses the findings for emotional engagement from the questionnaire.

4.3.2.2. Findings from Questionnaire

The responses to question 9 reflected the feelings of learning satisfaction and learning passion that students experienced in relation to PBL. Regarding the learning passion, the findings concur with the findings from the observation: none of the respondents felt any enjoyment and only 2 respondents (9%) felt enthusiasm, although 5 respondents (23%) reported they felt curiosity (see Figure 17). There was no report of boredom and 2 respondents could not relate to any feeling mentioned in the question. Responses to question 10, which asked participants to explain their choices in question 9, did not bring any clarity to these findings and it remained to be elucidated at the interview stage. Two other respondents said they felt overwhelmed and the analysis of the qualitative data revealed why participant 23 felt overwhelmed: “Initial start of the project had a lot to understand and grasp before beginning”. The other participant did not give any explanation.

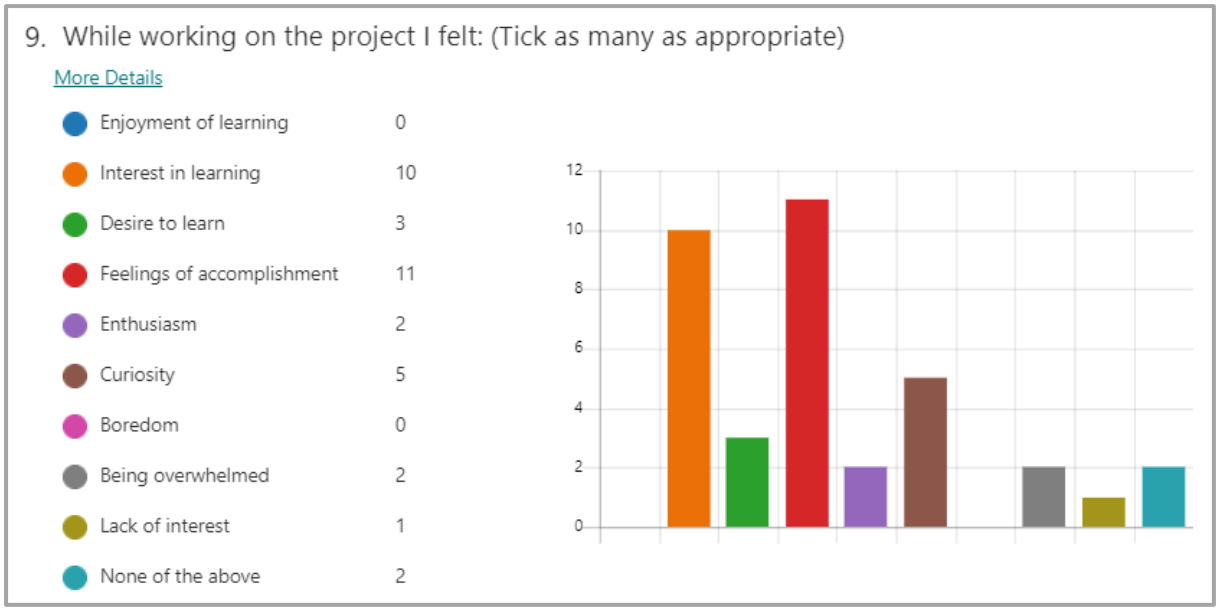


Figure 17. Responses in Relation to Learning Satisfaction and Learning Passion

The other choices at question 9 were related to feelings of learning satisfaction. 10 out of the 22 respondents felt interest in learning, while one responded reported lack of interest, and 11 (50%) had feelings of accomplishment. Only 3 respondents (14%) felt desire to learn. The analysis of the qualitative data from question 10 showed that 4 participants (18%) related the feelings of accomplishment with the end of the project. As participant 12 mentioned, “I felt accomplished when I submitted the project and it was finished”.

Two more ideas emerged from the analysis of the qualitative data. Firstly, 2 respondents (9%) related their feelings of learning satisfaction to the practical aspect of the project and the applicability of learning to a real-life situation, as quoted below:

> Participant 4: I felt after completing the project that I had accomplished something by putting my previous learning into practice in a more real-life scenario.

Secondly, 3 participants (14%) linked their interest in learning to PBL, as opposed to traditional learning, as described by:

> Participant 22: I’d personally rather project-based learning as opposed to reading slides and answering a standardised exam.

The questionnaire supplemented the findings from observation with findings related to students' feelings of belonging and being supported, which would have been hard to observe. Figure 18 presents the participants' responses to question 11. A high percentage (86.4%) of the participants enjoyed their collaboration with the project partner and 9% (2 participants) did not. These responses align with the participants' behaviour in the breakout rooms, where the general atmosphere was positive, appropriate for work and students were discussing in most instances. In class, the researcher could observe mainly the collaboration between project partners, there were only 2 artificial partnerships, where participants were not actual project partners. However, according to the responses in Figure 18, 40.9% of the participants agreed or strongly agreed with the statement 'I cooperated with other groups, not just the project partner' and only 22.7% disagreed, which means they collaborated outside class time. In addition, a high percentage of respondents (77.3% agreed or strongly agreed) felt supported by peers and lecturer, and also a large proportion felt part of a learning community (63.6% agreed or strongly agreed).

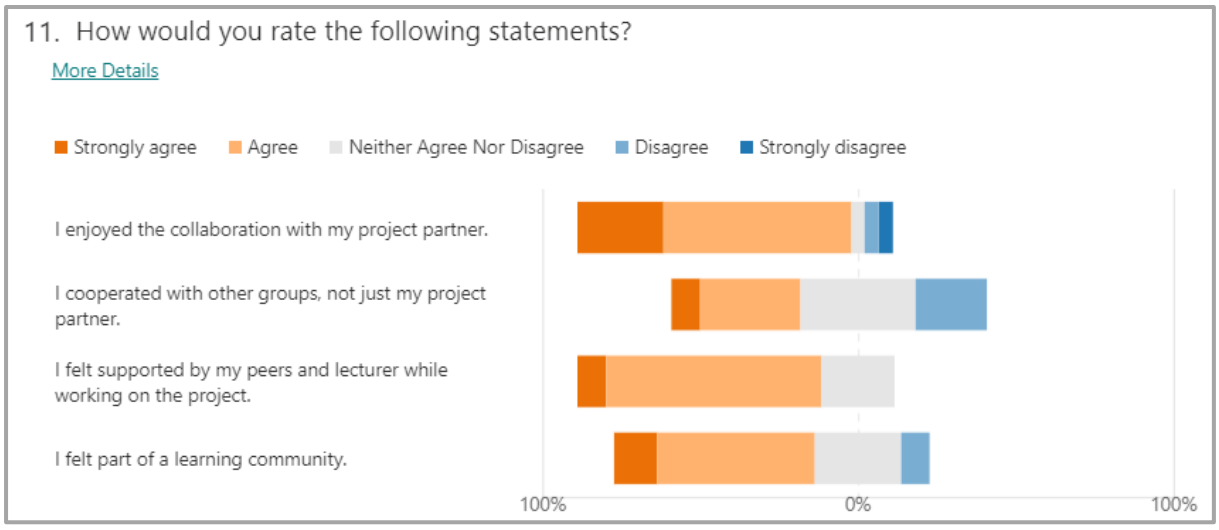


Figure 18. Responses Regarding Feelings of Belonging and Being Supported

Question 12 was qualitative and asked the participants to detail on the aspects of the collaboration they like or disliked. The most common positive aspects of the collaboration were the possibility to share ideas and help each other, which appeared 7 times (50% of responses), and the opportunity to share the workload, mentioned by 4 respondents.

> Participant 4 said: Working as a team halved the workload and also we were able to bounce ideas off of each when we were unsure.

Another finding is related to the opportunity of ‘meeting’ peers online, which was important for some students, considering that meeting in person was not possible for most of the year due to COVID-19 restrictions. In relation to that topic, one participant said:

> Participant 22: I got to spend time chatting and working with my partner for the group and other students, which allowed me to become friendly with them and ask for help in this subject as well as other subjects considering I didn’t know them at the beginning of year 3.

Another participant is cited below:

> Participant 9: Nice to work in project groups rather than being on your own because due to the virus we never get to see or talk to other students in our groups.

The participant who strongly disagreed with the statement ‘I enjoyed the collaboration with my project partner’ did not provide any explanation for his choice, but the participant who disagreed with the statement explained that “Generally I do not like group work. Prefer to do things on my own.”

The next section presents the findings for emotional engagement from interviews.

4.3.2.3. Findings from Interviews

Both findings from observation and questionnaire indicated a lack of enjoyment associated with project work. The researcher showed these results to the 5 participants to the interviews and asked their opinion. There were divergent interpretations of the reason for those results. Only two responses showed some degree of commonality and they were related to a theme that has emerged earlier: online learning. These two responses are cited below:

> Participant 1: Personally, for enjoyment... I suppose just the physicality of being able to talk to someone face to face. And I know we have meetings, but it's different when you're there and you know you can just have a proper conversation with them. I can't really think about any other reason.

> Participant 3: Well, I feel it's maybe because it's the actual online stuff at the moment 'cause people don't enjoy sitting in front of a laptop and then it's just this pressure to actually get through it and to get the grades and pass a year. I think

> that's probably why nobody answered that. Well, that's with me at the moment anyway. I don't enjoy college at the moment, 'cause I'm just sitting at home and...

Participant 2 did not realise there was a possibility to tick more boxes and he hesitated between ‘enjoyment’ and a few other options, whilst Participant 5 thought “It’s more a need of learning rather than enjoyment”.

In relation to learning satisfaction, the findings correlate with the findings from questionnaire: all participants had feelings of accomplishment when they finalised the project, as described by participant 3 and participant 4:

> Participant 3: I was happy when I had it submitted and done and I actually, well, I had a solution that was probably right, which I thought at that moment. And, well, I thought I did something … well, it was an actual problem that was given, so I actually solved something, so that was kind of good… well, good, yeah, yeah, so, yeah, it was a bit of a happy moment.
>
> Participant 4: Yeah, definitely, yeah. It’s… when you have something… a project… finished off you can… go off and, you know, have a treat for yourself or something…

All participants were willing to work, for example participant 3 said “I wanted to get it done and I wanted to get it done right”, and all felt motivated to do the project work. For example:

> Participant 1: When I work in group work, I want to get the right answer, I suppose, for the other ones as well, for the team members; whereas if I was working on my own, you know, I might just leave it up if I get an answer, I'll just leave it, you know. It makes me work a bit harder.

In order to understand better what motivated students to do the work and to learn, they were asked to compare project-based assessment with traditional written assessment and there was a consensus that the project was more motivating, for various reasons. Participant 1 found that a wrong result motivated her to try to find the right solution, which was totally different from studying for a traditional assessment: “You just sit down and you learn your notes”. Both participants 3 and 4 mentioned that the motivation to learn for a traditional assessment comes from time-pressure. Participant 3 also added that the real-life problem in the project was making it motivating, which concurs with participant’s 5 opinion, while one interviewee summarised:

> Participant 2: You'd be more motivated to learn probably I would say with the project... Yeah, so you'd be having to look into things going through a project

whereas studying… you could just be flying over something, thinking you understand it when you actually don't.

Asking if the participants found the project challenging, which could be a motivating factor for learning, revealed what each participant actually understood by ‘challenging’. All 5 participants agreed that the project was only somewhat challenging, but each defined a ‘challenging’ or a ‘not challeging’ project in a different way. Below are extract of the transcripts which show how each participant defined the term.

Participant 1: It wasn't challenging in a way, that, you know, it took us hours and hours of work to do. But it was challenging, I suppose, going back over stuff we might have done in two or three weeks. But it wasn't, you know, something we just sat and you could just do it with your eyes closed… Like I was saying, you know, if it's something easy and you’re just ticking the boxes and get it done, you don't get any satisfaction out of that.

Participant 2: Challenging like that I had to actually work. It wasn't just relaxing, sitting there clicking buttons. I had to think about what I was putting down… It wasn’t extremely challenging 'cause we've gone over the material and we had it all there in front of us if we wanted to see it. But yeah… if I said ‘no’ that would mean it was perfect, I didn't have to look at anything, I didn't have to look at any notes or anything like that.

Participant 3: Well, it was challenging in the sense that I couldn't just do it straight away and I had to look at the notes again, but it wasn't challenging as in I couldn’t do it. So yes, I had to go back to the slides at hypothesis testing and how to analyse the actual result 'cause it's nothing I had ever done before, so I'm not used to it. But it was doable, so it wasn't too much.

Participant 4: Conceptually it wasn’t challenging but just getting everything done properly was the challenge really. I didn’t find it too challenging but it was just… I suppose the biggest challenge was just getting it done.

Participant 5: I wouldn’t say it was challenging. Again, maybe overall… But yeah, it’s not that it’s challenging, it’s more to do with, I don’t know, to understand how to interpret the data for me. That’s the only downfall for me… Just kind of figuring out what the data mean, how to interpret it, how to explain it…

Regarding the sense of belonging and the students feeling supported by peers and lecturer, the findings from interviews correlated with the findings from questionnaire. All but one participant were happy to share work and to bounce ideas with their partners. Participant 5 was the only one who said “I’m not too big of a fan of group work, so if I can do it on my own, I’d rather do it on my own.” At the same time, participant 4 was very happy to work in a team and he viewed that as a great help for later, when they are going to work in industry:

Participant 4: And when you're doing it as a team as opposed to individually, it's a great help to be able to split up the workload like that, that's what we'd be doing when we're working, so it's good way to practice.

Data analysis in relation to students' emotional engagement identified a positive impact of PBL to emotional engagement and clarified what students understand by a challenging project. It partially clarified the issue of enjoyment of learning, which seems to have been affected by the online learning. Findings for the cognitive engagement theme are presented in the next section.

4.3.3. Findings Related to the Impact of PBL on Cognitive Engagement

This section presents the findings related to the impact PBL has on cognitive engagement. Indicators of positive and negative cognitive engagement were considered, including knowledge, perseverance, use of deep thinking and self-regulation as outlined in section 2.3 and in Table 4 in section 3.5.

4.3.3.1. Findings from Observation

Students' ability to do the analyses and to interpret the results were evaluated on a scale from 1 to 5, where 1 = no ability and 5 = a very great deal of ability. At the beginning of the class there was a small number of students (10%) who seemed to be at level 3 on the ability scale or at level 4 (45%), but as they progressed with their project work, more students showed higher ability to do the analyses or to interpret the results (5 students at level 3 and 13 at level 4 during the second visit, 2 students at level 3 and 13 at level 4 during the last visit) – see Figure 19.

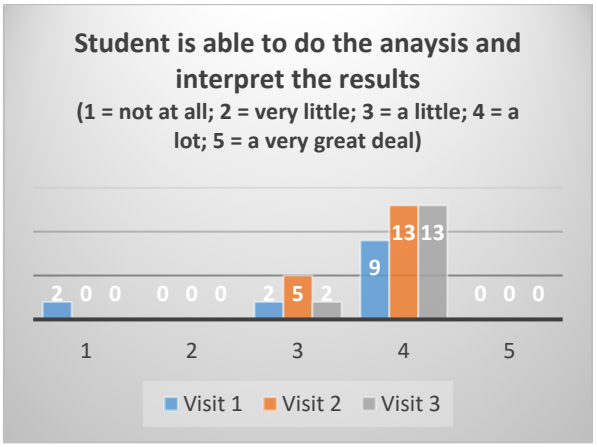


Figure 19. Number of Students Able to Do the Analysis and Interpret the Results and Degree of Ability

The results shown in Figure 19 were expected, considering that the number of students who had started working on the project prior to class was low. The observation notes bring additional explanations: at the beginning, many students were discussing the approach, tried to clarify certain issues or decided how to share the workload, therefore some of them did not go straight into the analysis. During the second and third visits, most of the students were either working on one of the analyses or were already at the interpretation phase and the researcher was able to quantify their level of ability based on what could see on the shared screens or on the questions students were asking.

The majority of participants seemed to persevere with their work for the duration of the session (see Figure 20 left), but the number decreased towards the end of the session (third visit). The researcher had recorded that she could not capture any sign of perseverance in four cases during the third visit. The right-hand side of Figure 20 correlates with the previous analysis. As students progressed with the analysis later in the session (captured during the second and the third visits), they were determined to get it done properly.

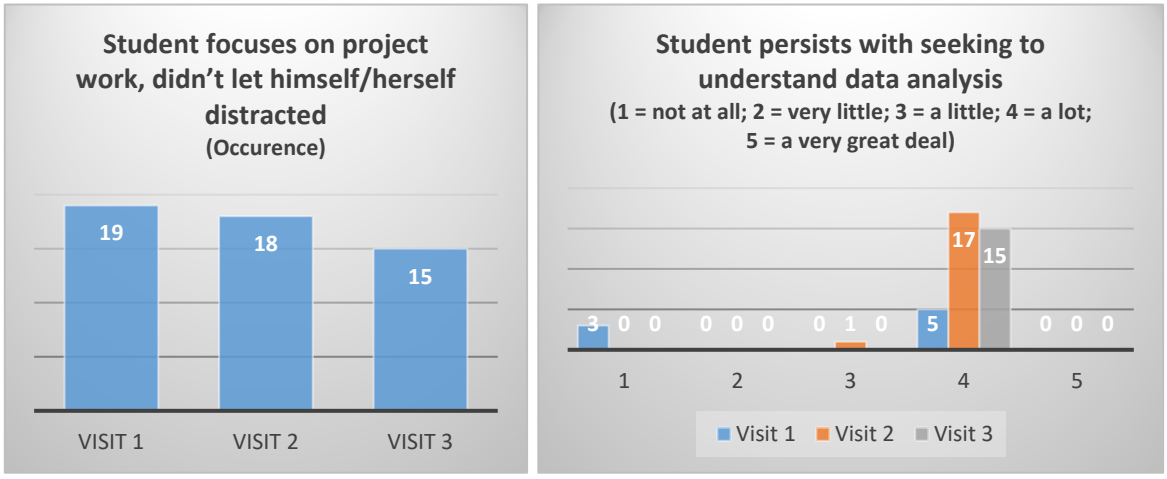


Figure 20. Number of Students Focusing on Work (Left) or Who Persist with Seeking to Understand the Analysis (Right)

A good number of participants demonstrated self-regulated and independent learning, as Figure 21 shows. During the first visit only 12 participants out of 20 (60%) showed a good level of independence, but the number remained relatively constant over the

entire session, as can be seen in Figure 21.The observation evaluated mainly the level of independence shown by the participants in the learning process and was based on (1) how advanced into the project work students were at different stages during the session and (2) the amount and type of questions they asked when the lecturer visited them in the breakout room.

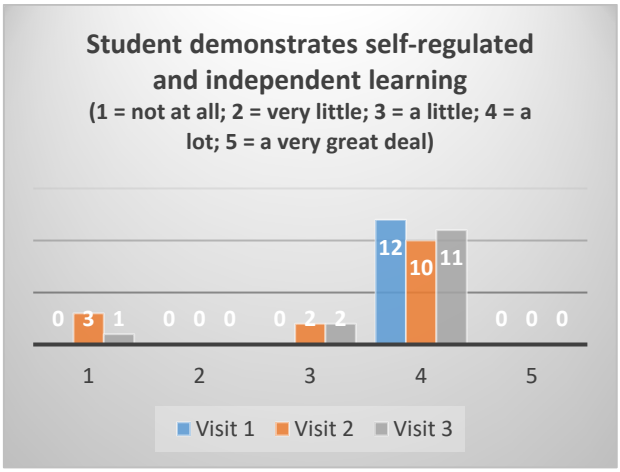


Figure 21. Number of Students who Demonstrated Self-Regulated and Independent Learning

The next section presents the findings related to cognitive engagement from the questionnaire.

4.3.3.2. Findings from Questionnaire

The responses to question 13 reflect the participants' perception of the way the project helped them build their knowledge. As Figure 22 shows, a high percentage of participants strongly agreed (between 4.5% and 13.6%) or agreed (between 45.5% and 86.4%) with all statements related to understanding the concepts behind the analyses that had to be performed, the circumstances when the analyses can be used and their ability to carry out the analyses and to interpret the results in the specific context. Therefore, over 50% of the students believed that PBL positively impacted their acquiring knowledge. There were small proportions who were not sure (neither agreed nor disagreed with those statements) and a very small percentage (4.5%) who did not agree with the statements related to the interpretation of results, both in the case of regression analysis and hypothesis testing.

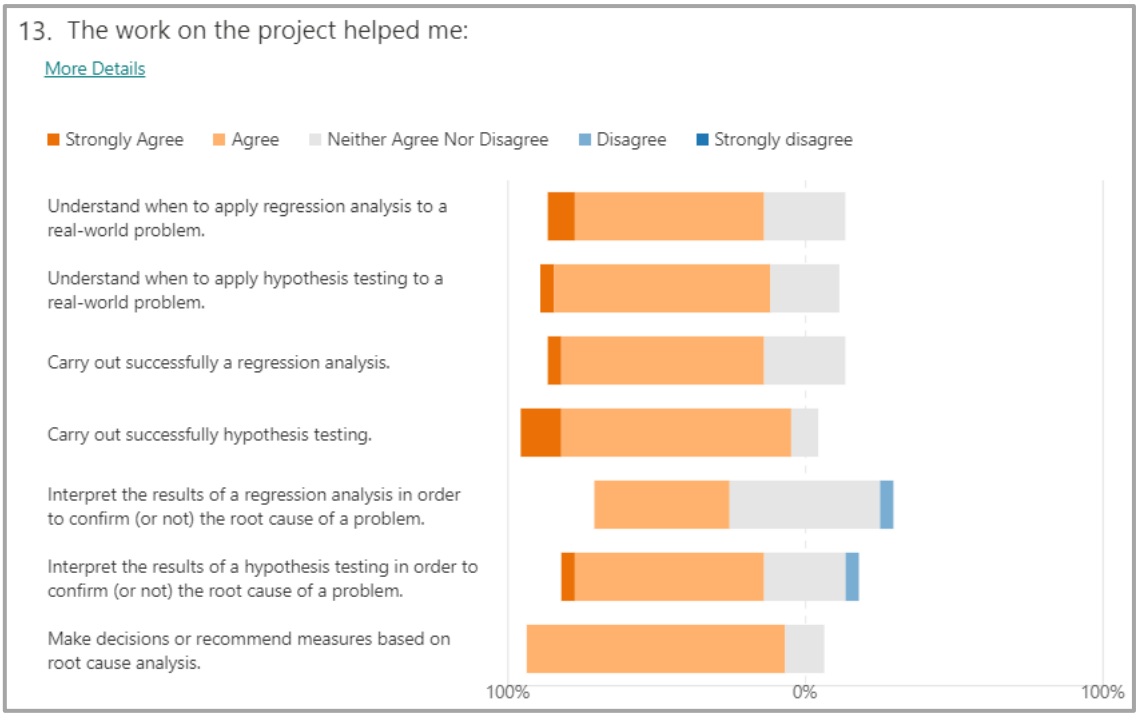


Figure 22. Responses Regarding Students' Knowledge Gained as a Consequence of PBL

The purpose of questions 14 (quantitative) and 15 (qualitative) was to find out if the participants found the project challenging and if so, to identify what the challenging aspects were, with a view to identify what factors influence their perseverance. A high proportion (68%) of the respondents considered the project challenging and the top challenge (mentioned 4 times out of 13 responses) was the interpretation of results. A small number of participants (only 2) found the regression analysis challenging, while other 3 respondents referred to data analysis. Surprisingly, 2 participants found the report writing a challenge.

Question 16 was asked in relation to the effect PBL had on self-regulated learning. Most of the participants (64%) thought PBL helped them to understand better what they knew and where they had gaps. Another good proportion of the respondents (55%) perceived PBL as helping them keeping up to date with work instead of letting it pile up, while 8 out of 22 participants (36%) thought PBL helped them to manage their time better (see Figure 23). PBL was equally appreciated as helpful in effectively organising college work (32%) and self-evaluating student performance (32%). Only

5 out of the 22 participants (23%) felt that PBL helped them work independently, which contradicts the findings from observation.

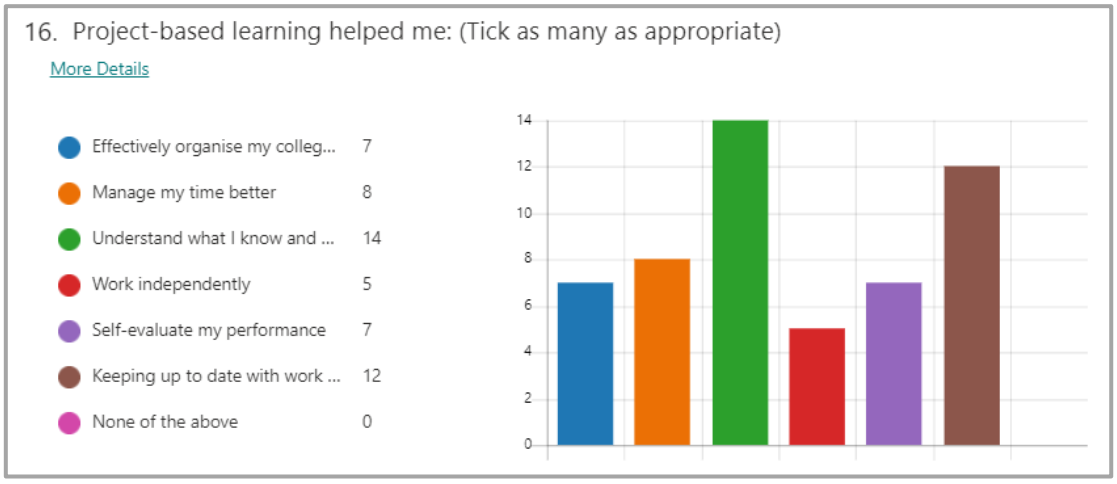


Figure 23. Responses Related to the Self-Regulated Learning

There were only two responses to the last question, which was trying to find out more about student experience based on project work, and they did not add any significant information.

Next section presents the findings in relation to cognitive engagement from interviews.

4.3.3.3. Findings from Interviews

The dominant idea emerging from the analysis of interview data was that PBL helped build up students' knowledge because of the practical work and the real-life application. Below are two quotes from interviews:

> Participant 2: If there was just a lecture and there was no context to it afterwards, then you kind of forget about it. Probably not great, but that's how I feel anyway.
>
> Participant 4: It might be different for other people, but for me, anyway, I learn best by actually doing stuff. Other people might learn by reading or by listening or… but the way I find it, personally, you have to go and do it a few times.

When comparing PBL with traditional learning, which usually happens in case of a written assessment or final examination, there was again consensus among the participants that PBL is better for learning. Some of the participants thought that was the case because when they study for a traditional exam they might skip some sections

either because they seem unimportant or because they think they know it. Participant's 3 explanation caught the researcher's attention:

> Participant 3: I'd say project work is actually some kind of deeper learning… It just sticks to your mind, in your head for a while longer and you learn it much better than if you just learn it for an assessment. 'cause you actually work on it for a longer period of time and you don't just learn it off for an assessment, use it and it's kind of gone out of your head again. So I'd say it's actually better learning and deeper.

Or, as another participant said:

> Participant 2: Definitely the project I'd feel you got more learning from. 'cause with study it feels like you're forcing yourself to do it, whereas with the project it kind of happens naturally when you have to go through things yourself. And you get a better understanding as well.

Three of the participants thought the group work influenced positively their accumulation of knowledge because you can "learn off the other people" (participant 1) and sharing ideas "helps you build your own skills" (participant 2), while four participants considered that PBL helped reinforce concepts by forcing them to go back and review notes and other sources. That proves the participants' perseverance with their work towards project completion.

Data from interviews also show a positive influence of PBL on self-regulated learning. All participants did additional research for the project and used various sources of information, such as YouTube videos, Minitab's own website or other specialised websites in order to understand better some concepts or to clarify some aspects of the project. As noted by:

> Participant 4: You have to go and do your own research even if you just wanted to find something more about what you're doing or where was used or something.

Three of the participants even indicated, directly or indirectly, that the project helped them see what they knew or what gaps they had, as participant 3 mentioned: "it definitely showed that I needed some more information and I got that".

Overall, the findings from the analysis show a positive impact of PBL on students' cognitive engagement. Participants to the study considered PBL better than traditional learning and more useful for building knowledge.

4.4. CONCLUSION

This chapter presented the key findings which emerged from the quantitative data in questionnaire and the qualitative data from all the three data collection tools – observation, questionnaire and interview. The findings were presented along the three main student engagement themes: behavioural engagement, emotional engagement and cognitive engagement. The chapter started with section 4.2, a short overview of the data analysis methods used in this study. Section 4.3 presented the findings thematically. Section 4.3.1 presented the impact of PBL on behavioural engagement of student with their learning. The findings showed a positive influence of PBL: active participation in class activity, interaction with peers and lecturer and good learning effort. A new factor that influences behavioural engagement emerged from the analysis: the online teaching and learning.

The findings for emotional engagement were presented in section 4.3.2. PBL induced feelings of satisfaction, accomplishment, willingness to learn, as well as a sense of belonging to a small learning community and of being supported by it. The impact of PBL on students' cognitive behaviour was presented in section 4.3.3. Students felt they got deeper knowledge with PBL, they persisted in their effort to learn and complete their work and found PBL helpful for self-evaluation and time management. Additional findings emerged from the data analysis. Some were related to factors that influenced behavioural engagement, such as the online teaching and learning or the class dedicated to project work, others contributed to understanding of students' interpretation of terms (e.g. challenging project, enjoyment of learning).

A few times the findings revealed contradictory evidence, but that is considered normal and is a result of the different data collection methods. Chapter 5 presents a thematic analysis and discussion of the main themes arising from the findings presented in this chapter.

5. CHAPTER FIVE: DISCUSSION

5.1. INTRODUCTION

The research findings in Chapter 4 are discussed in this chapter, with reference to the literature review in Chapter 2. This chapter addresses the aim of the research, to evaluate the impact of PBL method on student engagement, and, in particular, objective 5 as presented in Chapter 1 – to analyse the research findings, in conjunction with the literature, and present recommendations for further study. The chapter is structured into three main sub-sections. Section 5.2 discusses key findings of the study in relation to PBL impact student engagement along the three main themes of behavioural engagement, emotional engagement and cognitive engagement, and the additional findings in relation to the literature in the area. Section 5.3 examines how the study performed against the reliability and validity criteria identified in section 3.5.5. The contribution, as well as the limitations of the study are presented in section 5.4, which also addresses briefly recommendations for further study. A complete set of recommendations is further presented in Chapter 6.

5.2. THEMATIC DISCUSSION

The aim of this research was, as presented in Chapter 1, to evaluate the impact of PBL method on student engagement in the Six Sigma Green Belt Quality module. The data findings presented in Chapter 4 indicate that PBL had a predominantly positive impact on student engagement under the three main themes of behavioural engagement, emotional engagement and cognitive engagement. A number of conclusions, which pertain to the aim of the research, can be drawn from these findings, based on the thematic analysis carried out according to the methodology presented in section 4.2.1. They are further presented in the next sections.

5.2.1. PBL Impact on Behavioural Engagement

This section discusses the impact of PBL on three aspects of behavioural engagement: student participation in class, collaboration with peers and study time and effort.

5.2.1.1. Active Participation in Class

The findings in section 4.3.1 indicate an active participation of students in the project class. When they were asked about their participation in class, a large proportion of the respondents to the questionnaire (59%) declared to have actively been involved in the work, 64% asked for help when needed and 59% helped their peers. Screen sharing and discussions observed by the researcher also suggested an active participation in class of the majority of the participants, which is consistent with other research studies (Clark, 2017; Bilgin et al., 2015). The module having an activity-based learning approach, students are actively engaged in their work in class anyway; however, the project enhanced the active participation in class as it involved additional and different activities, as transpired from the qualitative findings: more interaction with the project partner, more discussions in relation to clarification of the project requirements, work sharing or interpretation of the results. These study results align to findings from literature (Kahu, 2014; Fredricks et al., 2004; Trowler, 2010; Kuh, 2009) as mentioned in section 2.4.

5.2.1.2. Collaboration with Peers

The impact of the PBL on collaboration with peers was very positive, as findings in section 4.3.1 prove. However, the collaboration was mainly within the partnership, both in and outside class. As the results of the questionnaire show, a very small percentage of participants collaborated with other peers (40.9%), and even that interaction was sporadic, according to the participants to interviews, which is not surprising, considering the COVID-19 restrictions. A large majority (86.4%) of the participants enjoyed the collaboration with their project partner and the qualitative findings evidence participants' appreciation of the social interaction and the positive impact on their learning – see Participant 22's comment: "It is good to have different views on problems and it can greatly improve how a problem is solved." A relevant explanation of the phenomenon is presented in Bender (2012): when students work in collaborative groups they learn through social context and interaction with their peers.

The findings presented in section 4.3.1 identified a factor that significantly influenced the peer-to-peer interaction and communication, as well as students' communication with their lecturer, namely the abrupt switch to online teaching and learning. This finding has emerged from the interviews' qualitative data. All interviewees

acknowledged the negative impact of online teaching to the way they communicate, their motivation to learn and their student life in general.

> Participant 4 emphasised: It's a bit awkward when you're trying to do something online. It's not quite the same as if you're beside him and you could just look over their shoulders. That's the problem there. It's harder to do that if you are online.

The participants confessed they felt uncomfortable when they had to talk online in front of their peers but found the possibility of discussing in breakout rooms very positive, which supports the qualitative findings from the questionnaire and findings from other studies (Reina, 2021).

These results build on existing evidence of negative impacts of the swift transition to online teaching. For example, Åhag et al. (2020) mention the lack of social interaction between the educator and the students, and between the students themselves as the major problem of the Swedish students during the pandemic, while Desrochersa et al. (2020) indicate that online teaching during the COVID-19 restrictions period was viewed unfavourably by students for two reasons: (1) it removed the hands-on learning experiences obtained with traditional in-person teaching, which they valued, and (2) it stopped the direct peer/student interchange.

Despite the negative aspects of online teaching and learning, the researcher has also identified some positive sides. The transition to online teaching and learning provided an opportunity for students to enhance their problem-solving skills and to acquire new skills related to new technology use, which are valuable skills in the 21st century work environment (Clark, 2017). Students found a variety of means to communicate with their peers and with the lecturer as both quantitative and qualitative findings in section 4.3.1 show.

5.2.1.3. Study Time and Effort

Findings in relation to study time and effort do not fit with the literature which suggests that PBL requires more time and effort than traditional learning (Balve & Albert, 2015; Lee et al., 2014). The results of this study were inconclusive. Neither the qualitative findings (see Figure 11 in section 4.3.1) nor the quantitative findings (see section 4.3.1.3) proved or disproved other research studies. Participants had different perceptions of the amount of work and time they had put into the project. The

qualitative findings suggest that the reason why some participants perceived project work as less effort- and time-consuming is the fact that project work is “more enjoyable”, “more interesting”, “a bit different” and “less stressful”, therefore it feels like it takes less time and effort, whilst traditional study requires memorising everything. The impact of PBL on emotional engagement is analysed in the next section.

5.2.2. PBL Impact on Emotional Engagement

This section discusses the impact of PBL on two aspects of emotional engagement: learning satisfaction, and motivation for learning.

5.2.2.1. Learning Satisfaction

The concept of learning satisfaction lacks consistency in definition, as found by Topala and Tomozii (2014). As advised in the above-mentioned study, the concept of learning satisfaction was approached in this research through related, better-explained concepts such as teamwork, collaboration, joy, fulfilment or desire to learn. Other aspects, related to online delivery, have been considered, such as ease to find material, appropriate support from lecturer, interaction with peers and lecturer (Rajabalee & Santally, 2020). The evaluation of all these aspects of learning satisfaction led to the conclusion that PBL had a positive impact on the participants’ learning satisfaction. As argued in section 5.2.1.2, PBL resulted in good collaboration between students and good teamwork. The participants did not feel shy in asking for help either from the lecturer “Any problems I had, I asked and they were explained and I took down notes so I could remember them again” (Participant 17) or from their peers “The breakout room allowed us to work with other students to help one another but also interact with the lecturer if needing help” (Participant 19). That suggests a feeling of being supported and belonging to a small learning community, which was confirmed by the responses to questions 11 and 12 of the questionnaire, as presented in section 4.3.2. Moreover, 90.9% of the respondents to the questionnaire agreed or strongly agreed with the statement in question 1, ‘I had enough class support material (notes and other resources) to attempt the project in my own time before the project class.’

Findings presented in section 4.3.2 indicate that the majority of the students experienced feelings of accomplishment and interest in learning, even, in a smaller

proportion, desire to learn or curiosity. However, the feeling of joy was totally missing from the participants' responses. Some of the participants to interviews explained that by the lack of enjoyment of college life in general due to the COVID-19 restrictions. One comment in particular drew the researcher's attention:

> Participant 3: You have to be really, really interested in it to actually enjoy that. And maybe it's just not everyone's interest to be into graphs and analysing data and stuff.

That is a very pertinent observation, which should be considered in future design of the project. Maybe if students can propose a topic for their project, something they have a genuine interest in, it would make them really enjoy their learning.

5.2.2.2. Motivation for Learning

Students' motivation for learning is their desire to participate in and to make efforts on learning (Koff & Mullis, 2011) and it can be intrinsic, arising from within the individual, or extrinsic, induced by the lecturer's rewards or punishment (Lin et al., 2017). There is a multitude of sources of intrinsic motivation, such as curiosity, confidence, attitude to learning, needs, competence, satisfaction (Duta et al., 2015; Shin, 2018). Among external factors that induce motivation for learning, one could enumerate engaging learning strategies, supportive environment, communication, reinforcement and interesting learning media (Duta et al., 2015; Nurul Hasana & Alifiani, 2018).

According to the findings in section 4.3.1, students seemed confident they could do the project, as 63.6% of the respondents to the questionnaire agreed or strongly agreed with the statement in question 5, 'I had enough knowledge before the class to attempt the project'. A relatively small number of respondents felt curiosity (23%), while the majority of the participants appeared to have experienced learning satisfaction, as the analysis in section 5.2.2.1 shows. Although the attitude of a student towards learning is an intrinsic characteristic, the participants' behaviour in breakout rooms observed by the researcher (see section 4.3.1.1) suggested a positive attitude towards learning.

The lecturer tried to induce motivation for learning through the use of an active learning strategy for the entire duration of the module (including PBL), the use of breakout rooms to stimulate communication, the use of multimedia (a combination of texts,

graphics, audio, animations) for the presentation of the course material, as well as strategies of behaviourist origin such as reinforcement and feedback. Four out of the five participants to the interview positively appreciated the opportunity offered by the project to reinforce some concepts previously presented to students. The qualitative findings from interviews (see section 4.3.2.3) show that the lecturer's efforts transformed into intrinsic motivation, as the interviewees revealed what motivated them: making a mistake (participant 1), the real-life application (participant 3), doing as opposed to listening or looking at some slides (participant 2, 4 and 5) – see extract below:

> Participant 4: It's something a bit different than just being in class and just doing assignments. You have to go and do your own research even if you just wanted to find something more about what you're doing or where was used or something. It's a bit easier to be motivated.

It can be concluded that PBL had a positive impact on students' motivation for learning, despite the lack of enthusiasm due to the COVID-19 restrictions and the forced online learning (see section 4.3.1) and difficulty to remain engaged and motivated while working from home, as other studies confirm (ASEE, 2020). The findings suggest that the PBL approach can improve students' motivation for learning, which leads to deeper learning and increased knowledge, as suggested by Noland and Richards (2014). The next section will analyse the impact of PBL on cognitive engagement.

5.2.3. PBL Impact on Cognitive Engagement

This section discusses the impact of PBL on three aspects of cognitive engagement: student knowledge, self-directed learning and the value of PBL for learning.

5.2.3.1. Student Knowledge

The findings in section 4.3.3 suggest that PBL helped students understand the concepts taught via project and the majority of the participants seemed confident of their ability to carry out regression analyses and hypothesis testing. It is to note that many participants linked this feeling of confidence in their ability to solve similar problems to shared cognition. Participant 7 felt positive about the "group members aiding each other", while Participant 12 mentioned "I could get help of my team if I didn't understand something, making it easier to learn". These findings are consistent

with the assumption that collaborative learning enhances students' learning by allowing them to learn from each other and to build the right knowledge (Robinson, 2013; Resnick, 1991). The project was found moderately challenging by the participants (see section 4.3.3), which, according to motivational research, is what students like and motivates them to learn. Too difficult or too easy tasks may not keep them interested in achieving the learning goals (Blumenfeld et al., 2006).

Another theme that arouse from cognitive engagement findings was how PBL positively impacted students' knowledge and understanding because of the use of a real-life scenario. Literature calls this focus on solving real-world problems an authentic learning experience, which is believed to contribute to increased understanding of the theoretical underpinnings of a field (Singer et al., 2020), as well as motivating students and stimulating cognitive engagement (Blumenfeld et al., 2006). It appears that findings from this study are in line with literature, namely drawing connections with the real-world do provide opportunities for students to need to understand and to apply skills and content they have learned.

It was mentioned in section 4.3.1 and section 4.3.2 that an unexpected finding that emerged from this study was the rather negative influence of the sudden transition to online delivery on student behavioural and emotional engagement. However, the study did not offer conclusive evidence of the impact on student knowledge. These results do not fit with other studies which suggest that the acquisition of knowledge during remote delivery is the same or may be even better than that of face-to-face delivery (Desrochersa et al., 2020; Brinson, 2015). That may be because this was not a comparative study.

5.2.3.2. Self-Directed Learning

Another theme that came through from the findings was how PBL gave participants more control over their learning. The findings in section 4.3.3 show that PBL has a positive influence on the students' ability to organise their work and manage their time and on their capability to identify gaps in their knowledge. Although only a small number of respondents to the questionnaire (5 out of the 22) perceived PBL as helping them work independently, all the interviewees suggested exactly that:

> Participant 4: When I find something I don't know I have to go back then and start reading over the notes and doing the examples again just to refresh it in your head.
>
> Participant 1: I write down every single thing you do so I go back over my notes to see if I was leaving out anything.
>
> Participant 2: I know I had to look at the notes and look up different parts, but I did know what I was doing at the same time.

These findings support previous reports which highlight the importance of PBL to foster independent learning (Chi et al., 2018; Harding et al., 2007; Bagheri et al., 2013). Students' ability to learn on their own is very important in a 21st century world that keeps changing and producing new information and knowledge every day (Guglielmino, 2013).

5.2.3.3. The Value of PBL for Learning

One strong theme that came through from the findings was the fact that the outcome of PBL is greater understanding of a topic and deeper learning. Research carried out in the last few years showed similar results (Chi et al., 2018; Cudney & Kanigolla, 2014; Bell, 2010). Participant 2 used the exact words "deeper learning", while another participant stated:

> Participant 4: You might not understand it that well before you do the project, but then when you go and you actually have to put in all of the different things into it to make it work, you get a better understanding of it.

It came across from this study that the participants have achieved deeper, meaningful learning as a result of the proposed project-based activity which simulated a real-life situation, fostered self-directed learning and implemented active learning. All participants exhibited preference for learning-by-doing:

> Participant 2: With the project it [learning] kind of just happens naturally when you have to go through things yourself. And you get a better understanding as well. … You're not really learning unless you're getting challenged to solve it.
>
> Participant 4: … better with projects 'cause there's something due so you have to actually go on and do it….
>
> Participant 5: Probably project would be more beneficial 'cause you're actually doing the practical work for it.

These findings are supported by plenty of evidence that active learning has the potential to enhance student learning, helping them build skills and competencies

relevant to their field (Chi et al., 2018; Berbegal et al., 2017; Çelik et al., 2018). There is also good evidence to support the constructivist theory discussed in section 2.6.1, which states that students construct their own knowledge by experiencing things (Daniela & Lytras, 2018) and the role of the teacher is mainly to support and facilitate learning (Richardson, 2003; Biesta, 2013).

One should note the role of technology in supporting a PBL initiative. The observation notes mention many times screen sharing and the use of Minitab (the software used for statistical analyses in the module), which is an indication of engagement and aligns with literature suggesting that technology gets students to participate to learning and helps sustain their interest (Blumenfeld et al., 2006). Students also used computer technology to collect information, organise and present it and, furthermore, to communicate in and outside class during the COVID-19-related restrictions. Therefore, technology can be viewed as an enabler of learning in a project-based setting.

The findings from this study suggest that PBL has the potential to enhance behavioural, emotional and cognitive engagement, which may lead to the conclusion that PBL is an effective mean of promoting learning and supporting the acquisition of both technical and soft skills in an engineering module. The next section will discuss the reliability and validity of these results.

5.3. RELIABILITY AND VALIDITY

The reliability and validity of a study indicate its trustworthiness or the extent to which the research findings reflect the world that researcher is seeking to explore (Fox, 1998). The validity of this study was ensured by triangulation, as specified in the research method and described in section 3.5.5. Three tools were used for data collection, namely observation, questionnaire and interview. The tools were reviewed by peers and the supervisory team and were piloted with a small group of students (see section 3.5.6) to ensure that the questions and the structure of the tools fully represented the three themes of student engagement identified in literature, as detailed in section 2.3. The findings from the three data sources agreed, supporting the conclusions from each. In order to increase the accuracy in reporting the

perception of the impact of PBL on the participants' engagement and to give a true picture of this impact, the researcher used what is called in literature "low inference descriptors" (Baker, 2006), namely direct quotation from qualitative data. Video recording was used for interviews to avoid inaccurate notes and note-taking was practiced in observation.

The reliability of the study was ensured by the robust research method (see section 3.5) and data analysis method (see section 4.2), which provide consistency of the procedure and the results. An inter-rater reliability check of quality data was performed using Cohen's kappa coefficient (see section 3.5.5). The thesis supervisor offered to act as the second rater and, using the colour coding for the main themes and following the data analysis methodology presented in section 4.2.1, she highlighted the text in two interview transcripts (Participant 2 and Participant 3). Each extract was placed on a table and coded with B (behavioural), E (emotional), C (cognitive), O (other) or N (nothing) according to the classification considered appropriate by the researcher and by the supervisor (see Table 9).

Table 9. Example of Classification of Extracts from Interview Transcripts

Item	Researcher	Supervisor	Combined
Living in the same house easier to talk, use MS Office	B	B	BB
Living in the same house easier to talk, use MS Office	E	E	EE
Working well together	E	E	EE
Questions came up and we could clarify	B	C	BC

The combined codes in the last column were counted and organised in a table used for the calculation of the percent agreement and the Cohen's kappa coefficient (see Table 10).

Table 10. Table for Calculating % Agreement and Cohen's Kappa Coefficient

Supervisor / Researcher	B	E	C	O	N	Total
B	24	1	2	1	3	**31**
E	3	26	4	0	3	**36**
C	3	2	18	1	5	**29**
O	2	2	1	8	1	**14**
N	2	0	1	1	0	**4**
Total	**34**	**31**	**26**	**11**	**12**	**114**

Agreement	Kappa coefficient
0.67	**0.56**

The 0.67 (67%) value shows the agreement among the two raters, researcher and supervisor, which is acceptable, considering that perfect agreement is rarely achieved (McHugh, 2012). The remaining 33% show divergent interpretation of data by the two raters. However, McHugh (2012) is citing Cohen who said that "there is no criterion for the 'correctness' of judgments". Cohen also introduced the kappa coefficient which takes into account the possibility of raters guessing, therefore is considered a more robust measure than the simple percent agreement.

Cohen suggested the kappa coefficient be interpreted as follows: values ≤ 0 as indicating no agreement and 0.01–0.20 as none to slight, 0.21–0.40 as fair, 0.41– 0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1.00 as almost perfect agreement (McHugh, 2012). According to these guidelines, the study's kappa coefficient of 0.56 suggests a moderate agreement. As rater independence and other factors are not well supported by the model and it is hard to be directly interpreted, literature suggests that it is common for researchers to accept low kappa values in their interrater reliability studies (McHugh, 2012; Warrens, 2014). Furthermore, as the researcher and supervisor are very familiar with the classification of student engagement, agreement occurring by chance is quite unlikely, therefore the study can even rely on the 67%

agreement, as indicated by literature (McHugh, 2012). The next section discusses the contribution and the limitations of this study.

5.4. CONTRIBUTION AND LIMITATION OF THE STUDY

This study has contributed to knowledge in a few ways. This research analysed and discussed in detail the impact of PBL on all three aspects of student engagement – behavioural, emotional and cognitive – at third level education, in a Six Sigma module. Other studies looked at all aspects of engagement but at secondary level education (Johnson & Delawsky, 2013), or they considered only some aspects of engagement (Shin, 2018; Balve & Albert, 2015; Anderson, 2017), or a different subject (Hung et al., 2012; Clark, 2017; Dixson, 2015), or even the same topic (Six Sigma) but focused only on the cognitive engagement (Cudney & Kanigolla, 2014). Moreover, the study offered the researcher a very good understanding of the way the impact of PBL on student engagement is perceived by the students themselves. That is valuable information which will inform the lecturer's teaching strategy for the module.

This research has a number of limitations. The sample of participants to the study was small, it represented only a fraction of the 3rd year students studying engineering in GMIT. The study was limited to one module Six Sigma Green Belt Quality in one department, Mechanical and Industrial Engineering, at GMIT. The study focused on a short time frame; data were collected over four weeks. A larger and more diversified sample of engineering students and a longer period of time would provide more robust results and would lead to more generalisable conclusions. Qualitative research is notable for lack of external reliability (or generalisability) (Baker, 2006). However, as argued in section 3.5.5, it was never the intention of the researcher to generalise these findings. The aim has always been an in-depth understanding of the impact of PBL on student engagement in the particular engineering module of Six Sigma Green Belt Quality and, based on that, an improvement of the lecturer's teaching strategy. Nevertheless, considering the nature of the module, it is believed that what is learned from this study can be transferred to other engineering modules studied at GMIT.

Another limitation of the study refers to the selection of participants, which was based on convenience and purposive sampling and not a random selection of students. That

might have led to some bias, as students selected that way could have possibly been more representative of more engaged students. Furthermore, the responses to the qualitative questions of the questionnaire were low, although the response rate was high. The questionnaire responses were anonymous for ethical reasons and to avoid bias but that means the researcher missed out the opportunity to get more in-depth quality data.

Finally, this was not a comparative study and neither used a control group of students not using PBL. Future studies might consider a comparative study, with a well-considered design, which should address the challenges of a comparative study (for example, using the same cohort of students), in order to demonstrate statistically the advantage of the PBL approach in terms of engaging students in their learning, as opposed to traditional teaching methods.

5.5. CONCLUSIONS

This chapter analysed the data findings and discussed them with reference to the literature. The analysis in section 5.2.1 showed similarities with other research studies in terms of impact of PBL on behavioural engagement: PBL causes students to be more involved in their class activities and engage students in collaboration with their peers despite potential barriers to communication. The results of this study were inconclusive in relation to study time and effort, and do not fit with the literature which suggests that PBL requires more time and effort than traditional learning. Section 5.2.2 discussed the impact of PBL on emotional engagement. It was concluded that participation in PBL motivates students to learn and it has a positive impact on learning satisfaction. The majority of the participants experienced feelings of accomplishment and interest in learning, even, in a smaller proportion, desire to learn or curiosity, although the feeling of joy was totally missing from their responses. In relation to cognitive engagement, section 5.2.3 revealed that PBL has the potential to enhance student learning due to several factors: collaboration with peers, real-life simulation which makes learning more meaningful and relevant for students, and increased motivation, which leads to deeper learning and increased knowledge. Furthermore, PBL gives students more control over their learning, transforming them in independent learners.

Section 5.3 addressed the validity and reliability of the study. It can be concluded that the robust research method and the coherent data analysis method together with the use of triangulation and the inter-rater reliability check make the study trustworthy. Finally, section 5.4 highlighted the contribution of the study to knowledge and its limitations. Despite the small scale, which cannot confer generalisability, the study has merit in offering an in-depth understanding of the impact of PBL on student engagement in the Six Sigma Green Belt Quality and of the students' perception of this impact. That can be used by the researcher to improve her teaching strategy. Furthermore, considering the nature of the module, the learnings from this study could be transferred to other engineering modules studied at GMIT.

The last chapter of this thesis provides a summary conclusion of the study and outlines the key recommendations for further work.

6. CHAPTER SIX. FINAL CONCLUSIONS

6.1. INTRODUCTION

This research aimed to evaluate the impact of PBL method on student engagement in the Six Sigma Green Belt Quality module with the aid of a case study. Based on a quantitative and qualitative analysis of data related to student behavioural, emotional and cognitive engagement, it can be concluded that PBL has, on balance, a positive impact on student engagement with learning in the Six Sigma Green Belt Quality module. The results indicate that PBL can cause students to be more involved in their class activities and to collaborate with their peers. It can also increase students' motivation to learn and it has a positive impact on their learning satisfaction. Furthermore, the analysis of the study results revealed that PBL has the potential to enhance student learning. Several factors which lead to deeper learning and increased knowledge were identified, such as collaboration with peers, increased motivation and the real-life simulation, which makes learning more meaningful and relevant. PBL gives students more control over their learning, transforming them in independent learners.

A summary of the study along the thesis objectives formulated in section 1.2 are presented next, followed by recommendations for further work and some concluding thoughts on the study.

6.2. SUMMARY OF THE STUDY

This section presents a summary of the study with respect to the initial objectives stated at the beginning of the thesis in section 1.2.

6.2.1. Objective 1: To clarify key terminology relevant to the study, such as student engagement and project-based learning

The literature analysis in Chapter 2 addressed the first objective of the study, namely it clarified the term 'student engagement' and 'project-based learning' in the context of this research. A definition of engagement in the classroom was adopted:

> Student engagement is the extent to which students actively engage by thinking, talking, and interacting with the content of a course, the other students in the course, and the instructor (Dixson, 2015).

Indicators for its measurement were identified along three themes: behavioural, emotional and cognitive engagement, as shown in Figure 1, section 2.3. These indicators were further used to inform the design of the data collection tools, as discussed in Chapter 3, section 3.5, where observed factors and types of questions which show student engagement along the three themes are discussed (see Table 5 and Table 6).

PBL was defined in the context of the active learning approach to pedagogy, which engages students in the learning process through activities in the classroom, instead of passively listening to the lecturer. As literature did not offer a single comprehensive definition of PBL, the author proposed the following working definition for this study:

> PBL is a teaching strategy that aims to achieve student learning via participating in a project designed to address a real-world problem. Students work in a small team and the lecturer provides ongoing instruction, guidance and support. Formative assessment is conducted during learning and summative assessment is completed at the end of the project, after learning has occurred.

Creating real-life problems for students to solve is key in PBL. Using real-life scenarios, giving students independence in making their own decisions, encouraging collaboration and discussion, PBL helps students create their own knowledge instead of being taught. Using individual as well as cooperative learning strategies, students develop and apply knowledge to solve problems, and generate new knowledge using cognitive processes.

6.2.2. Objective 2: To critically evaluate literature related to project-based learning and its implementation to engineering programmes with a view to informing the research design

Section 2.4 in Chapter 2 identified the PBL method as an active learning strategy that has been applied successfully in STEM subjects (Balve & Albert, 2015; Sharma et al., 2020; Eugene, 2006; Hung et al., 2012; Lee et al., 2014). Literature indicated that PBL is an effective teaching strategy to promote student engagement, as well as constructing professional knowledge and soft skills, such as teamwork, collaboration,

communication and problem-solving (Guo et al., 2020). The characteristics of PBL, as summarised in Figure 2 in Chapter 2, informed the design of the PBL approach in terms of learning tasks, assessment strategy and strategy for an effective and meaningful feedback, as presented in section 2.6.

The studies on PBL in higher education reviewed in section 2.5 showed that student engagement was evaluated by various methods: interviews, questionnaires, journals as well as artefacts (assessed by rubrics) (Guo et al., 2020). These findings informed the decision regarding the data collection methods selected in section 3.5 for this study.

Chapter 5 presents the analysis and discussion of the findings of this study, which concluded that PBL approach is an effective teaching strategy to enhance student engagement along all three themes: behavioural, emotional and cognitive. These findings are comparable to those of other research studies discussed in section 2.5.

6.2.3. Objective 3: To perform a literature analysis of the learning theories that underpin PBL as a learning tool with a view to informing the pedagogical framework for the PBL strategy

Section 2.6 in Chapter 2 has reviewed three learning theories with a view to support the PBL strategy and to create a strong pedagogical framework for the design of the PBL learning activities, assessment and feedback. The theories that stood out as compatible with PBL were constructivism, constructionism and behaviourism. Constructivism and constructionism in particular can contribute to student-centred learning and student engagement, whilst helping students acquire the skills necessary in industry. The learning theory underpinning the PBL strategy for this study is constructivism, with elements from constructionism and behaviourism. Piaget's constructivism dictated the design of the learning activities, as it promotes the use of a real-life scenario and problem-solving. Also rooted in constructivism is the role of the lecturer as facilitator of learning rather than teacher (Biesta, 2013; Richardson, 2003). Borrowed from Papert's constructionism were the construction of visual aids for the project analysis, similar to the artefacts of constructionism, and the application of abstract concepts to real situations (Daniela & Lytras, 2018; Ackermann, 2001). The

decomposition of complex tasks into a sequence of smaller tasks, and the extensive use of feedback to guide the student towards achieving targets are elements of behaviourism that were incorporated in the assessment (Agarkar & Brock, 2017; Stewart, 2012). These theories influenced the design of the PBL strategy used in this study to evaluate its impact on student engagement.

The findings analysis in Chapter 5 was discussed relative to the literature review and it concluded that there was good evidence to support the constructivist theory discussed in section 2.6.1, which states that students construct their own knowledge by experiencing things and the role of the teacher is mainly to support and facilitate learning.

6.2.4. Objective 4: To design and conduct a case study aimed at evaluating the impact of project-based learning method on student engagement in the Six Sigma Green Belt Quality module

In Chapter 3 a research methodological framework was constructed, which permitted to position the research in the interpretivist paradigm, with elements from pragmatism and positivism. The choice of research paradigm was dictated by the aim of the study, which involved the researcher's interpretation of the students' interpretation of the impact of PBL on their engagement. The research paradigm together with the research question and the research type determined the choice of methodology, the case study, and the choice of mixed data collection methods, which completed the research methodological framework. The mixed methods enabled multiple sources of evidence for an in-depth and broad investigation. The data collection tools included observation, questionnaire and interview. Their design was informed by the indicators for student engagement identified in section 2.3. Special attention was given to ethical considerations when conducting the study, to the validity and the reliability of the study. Section 5.3 concluded that the robust research method and the coherent data analysis method together with the use of triangulation and the inter-rater reliability check made the study trustworthy.

Chapter 4 presented the key findings which emerged from the quantitative data and the qualitative data collected with the three data collection tools – observation,

questionnaire and interview. The findings were presented along the three main student engagement themes – behavioural engagement, emotional engagement and cognitive engagement – and reported a positive impact of PBL on student engagement with learning in the Six Sigma Green Belt Quality module.

6.2.5. Objective 5: To analyse the research findings, in conjunction with the literature, and present recommendations for further study

Chapter 5 analysed the data findings and discussed them with reference to the literature review in Chapter 2. The analysis showed similarities with other research studies in terms of impact of PBL on behavioural engagement: PBL causes students to be more involved in their class activities and engage students in collaboration with their peers despite potential barriers to communication. The results of this study were inconclusive in relation to study time and effort, and do not fit with the literature which suggests that PBL requires more time and effort than traditional learning. In terms of the impact of PBL on emotional engagement, it was concluded that participation in PBL motivates students to learn and it has a positive impact on learning satisfaction. The majority of the participants experienced feelings of accomplishment and interest in learning, even, in a smaller proportion, desire to learn or curiosity, although the feeling of joy was totally missing from their responses. In relation to cognitive engagement, the analysis revealed that PBL has the potential to enhance student learning due to several factors: collaboration with peers, real-life simulation which makes learning more meaningful and relevant for students, and increased motivation, which leads to deeper learning and increased knowledge. Furthermore, PBL gives students more control over their learning, transforming them in independent learners.

Chapter 5 concluded that despite being a relatively small-scale case study, which cannot confer generalisability, the study has merit in offering an in-depth understanding of the impact of PBL on the case under investigation, namely, student engagement in the Six Sigma Green Belt Quality and of the students' perception of this impact. That can be used by the researcher to improve her teaching strategy in future iterations of the module. Furthermore, considering the nature of the module, the learnings from this study could be transferred to other engineering modules studied at GMIT.

The next section addresses the recommendations for further work arising from this study.

6.3. RECOMMENDATIONS FOR FURTHER RESEARCH

One limitation of this research identified in section 5.4 is the scale of the study. The sample size of 22 students, although representative for the cohort that was taking the Six Sigma Green Belt Quality module (37 students), is relatively limited. More case studies, modelled on the process outlined here, including a variety of disciplines, degree levels and years of study are necessary to increase and confirm (or otherwise) the findings of this study. Although such a research project would contribute to a great extent to the verification of the impact of the PBL approach on student engagement in various classroom contexts, it may require a huge effort and possibly training of lecturers who might not be familiar with the PBL approach or might be reluctant to implement it. Future work would then need to address a training programme on PBL strategy for lecturers and possibly mentoring.

To better understand the implications of these results, future studies could compare the student engagement in two scenarios: PBL approach versus traditional teaching. As mentioned in section 5.4, this was a case study that tried to understand the impact of PBL on student engagement and how students themselves perceive this impact; it was not a comparative study. Qualitative data showed that students prefer PBL to traditional learning, but a separate study should be conducted in order to compare all aspects of student engagement in the two scenarios (perhaps, by means of different and sequential learning processes – with the same cohort – and rigorous attention to potential variables).

The study concluded that PBL has a positive impact on student engagement with learning in the Six Sigma Green Belt Quality module. Students engage more in class activity, collaborate more with their peers, feel motivated to learn and are satisfied with their learning, and they perceive PBL as an enabler of deep learning and increased knowledge. Further studies could build on these findings and investigate the correlation between engagement and academic performance. The engagement with the module might be beneficial to the student learning experience, but it would be

interesting to see if it has a positive impact on the student academic performance as well. This thesis concludes with some final reflections on the study in the next section.

7. EPILOGUE

When I started writing this thesis, I found it difficult to switch from my engineering domain to social science, a totally new field for me. I considered it inappropriate to use the first person in my writing, therefore I referred to myself as “author” or “researcher” throughout. Now, at the end of the journey, I feel more comfortable in this new area and ready to write my final thoughts using the first person.

The literature review suggested a positive impact of PBL on student engagement. However, little is known about the impact of PBL on all aspects of engagement in a Six Sigma module taught on an engineering programme. The study I carried out for the Six Sigma Gren Belt Quality module brought new insights into the way the impact of PBL on three student engagement aspects (behavioural, emotional and cognitive) is perceived by the students themselves. The choice of mixed methods approach and the sequence the three data collection tools were used was very appropriate as qualitative data collected towards the end of the study enriched the information as well as the validity of the research.

The study was constantly guided by the aim and the objectives of the research and that can be seen in the cross-referencing throughout the thesis. As a novice researcher in the field, I have grown to appreciate the rigour of the research process and to give proper consideration to the ethical implications of the study, especially as I am also a lecturer to the participants to this research. Although I carried out the primary research myself, I appreciate the importance of the collaboration with experts and peers for the validation of the data collection tools, as well as the student input. I cannot over-emphasise the importance of student opinion for the success of the study and for its value for me as a lecturer. Students provided very insightful contributions to the understanding of the way they perceive PBL and how this teaching strategy engages them in the learning process. I will use the findings from this research to further explore the PBL in my modules, in the following directions: the possibility that students can choose their own project, which might lead to actual enjoyment of learning, the relationship between the PBL approach and academic performance, or even the replacement of traditional teaching with PBL in a larger proportion.

For those considering a PBL approach as part of their teaching practice, it is very important to consider the use of learning theories to design a meaningful and relevant project. It is equally important to assume a new role, that of a facilitator rather than teacher and to empower the students to be responsible for their own learning.

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9. APPENDICES

APPENDIX 1. PROJECT DESCRIPTION

Regression and Hypothesis Testing Project

After the root causes of a problem were analysed, everybody agreed that it is quite likely that the temperature in the room influences the quality of the product.

The technician collected randomly 50 products over 5 days, at different times of the day, and recorded the temperature in the room at the moment of collection and the measured diameter of the part (see Table 1).

Table 1

Temperature (^{0}C)	Diameter (mm)
22.9	102.14
21.6	100.52
22.7	101.03
21.6	102.82
20.3	102.77
21.8	102.19
21.0	102.30
22.5	104.04
21.7	100.36
20.7	104.55
21.0	103.22
20.9	103.58
22.5	103.96
22.2	101.58
21.5	103.52
22.5	102.19
21.9	103.85
20.7	101.63
21.3	103.01
20.4	104.21
20.0	100.08
22.6	100.71
21.0	101.29
20.3	100.26
21.6	103.75
23.0	101.74
20.9	102.57
22.6	103.55
20.1	101.20

20.5	104.65
20.6	101.92
21.4	101.47
22.3	102.06
22.7	100.49
21.5	104.35
22.1	104.65
21.2	103.19
22.8	101.80
22.1	101.09
21.1	101.97
22.0	101.62
21.7	104.57
22.9	102.02
21.0	100.61
21.5	104.76
22.7	102.11
20.2	100.21
21.0	101.33
22.4	101.56
20.4	104.34

(a) Carry out a regression analysis to check if there is a correlation between temperature and the part diameter. Use Minitab.

(30 Marks)

(b) To gather more evidence, carry out an experiment. Maintain the temperature at 21^0C degrees Celsius, collect 10 random parts and measure the diameter. Change the temperature to 23^0C, collect 10 more parts, and measure the diameter. Data are presented in Table 2.

Table 2

Sample no.	Diameter at 21^0C	Diameter at 23^0C
1	101.09	104.94
2	104.87	100.57
3	101.95	102.53
4	100.80	100.68
5	102.02	101.52
6	102.37	100.93
7	102.33	101.83

8	102.40	103.64
9	100.68	102.93
10	102.80	101.43

Perform an appropriate hypothesis test and check if there is any difference in the mean of the part diameter at 21^0C and at 23^0C. Use Minitab.

(30 Marks)

(c) Write a quality report describing your data analysis (done at part a and part b) and summarise your conclusions. Include any recommendations that you would make to the production manager.

(40 Marks)

Upload both Project report and Minitab file to Moodle.

APPENDIX 2. PARTICIPANT INFORMATION LEAFLET

1. **Working Title of the Study:**

AN EVALUATION OF THE IMPACT OF PROJECT-BASED LEARNING ON STUDENT ENGAGEMENT IN THE SIX SIGMA GREEN BELT QUALITY MODULE AT GALWAY-MAYO INSTITUTE OF TECHNOLOGY IRELAND – A CASE STUDY

2. **Introduction to the Study:**

This study investigates how project-based learning influences student engagement with the Six Sigma Green Belt Quality module. The main aspects of engagement that will be studied are: learning effort, participation in class, communication, learning satisfaction, feeling of being supported by lecturer and peers, sense of belonging, learning passion, knowledge, perseverance and resilience in the face of challenges, use of deep strategies, self-regulation. The results of the study will form the basis of an improved teaching strategy for the Six Sigma Green Belt Quality module as well as other engineering modules.

3. **Research Procedures:**

The study involves voluntary participation of students into:

- Observational study (researcher observes student's behaviour during execution of a particular task)
- Completing questionnaire
- 1-to-1 interview.

The participation to the study is voluntary. There will be no penalty if you do not want to participate. You can be assured that your grades will not be affected whether or not you decide to take part in this research study.

The participants to the study are selected randomly from the entire population of 3rd year Mechanical Engineering students. A limited number of students will be selected.

4. **Benefits of the Research:**

Your potential benefits resulting from the research may be:

- Opportunity to improve your learning experience, as well as that of subsequent cohorts of students

- Opportunity to reflect on your learning
- Increased self-esteem, increased self-awareness
- Satisfaction in having created valuable knowledge and contributing to science
- A greater personal understanding of the research area under observation
- Enjoyment and sense of belonging and empowerment.

Incentives for and payments associated with participation in the research study will not be considered. You should not expect any form of financial reward.

5. **Risks of the Research**:

A few potential risks of the research are listed below, together with mitigation measures:

- The researcher is your lecturer at the same time. As participant to the study, you may feel under pressure to volunteer or may not wish to offend the lecturer by refusing to participate. Remember that the study is voluntary and there will be no penalty if you don't want to participate. The possibility of appointing an individual from outside the department to act as an intermediary may be explored.
- You may not behave naturally during the observation, you may feel awkward being watched. The researcher will try to put you at ease, starting with some explanations and short activities before starting the actual observation process.
- You may find it an unusual experience to be asked to complete a questionnaire. The questionnaire is part of the research study, *it is not an assessment or a test*.
- You may feel embarrassed or uncomfortable. If that's the case, you should remember that the participation to the study is voluntary and you can decide not to participate or to withdraw without being penalised in any way.

6. **Exclusion from Participation**: You cannot participate in this study if *you are under 18.*

7. **Confidentiality:**

Data collected/files will be securely stored on the researcher's passworded computer, according to GMIT security and data protection rules.

The findings of the research study will be included in a final thesis report and publications. No identifying factors relating to participants will be in evidence in the final thesis report and/or any disseminated research (i.e. conference papers and/or

presentations, publications, etc.). Those who will have access to your identity include: members of the Research Advisory Panel, internal examiners and external examiner(s).

8. **Compensation:** This study is covered by standard institutional indemnity insurance. Nothing in this document restricts or curtails your rights.

9. **Voluntary Participation:** You have volunteered to participate in this study. If you wish to withdraw, please contact the researcher within one month of initial participation. If you decide not to participate or if you withdraw you will not be penalised and will not give up any benefits that you had before entering the study.

10. **Stopping the Study:** You understand that the researcher(s) may withdraw you from participation in the study at any time without your consent.

11. **Permission**: This research has approval from the MA in Teaching & Learning Research Ethics Committee, GMIT.

12. **Further Information:** You can get more information or answers to your questions about the study, your participation in the study and your rights, from *Aurora Dimache* who can be e-mailed at *aurora.dimache@gmit.ie*.

13. **New Information Arising:** If the researcher or members of the Research Advisory Panel learn of important new information that might affect your desire to remain in the study, or if any conflicts of interest emerge during the course of the study, you will be informed at once.

APPENDIX 3. INFORMED CONSENT FORM 1

INDIVIDUAL RESEARCH PARTICIPANTS

Working Title:

AN EVALUATION OF THE IMPACT OF PROJECT-BASED LEARNING ON STUDENT ENGAGEMENT IN THE SIX SIGMA GREEN BELT QUALITY MODULE AT GALWAY-MAYO INSTITUTE OF TECHNOLOGY IRELAND – A CASE STUDY

Principal Researcher:

Aurora Dimache

Background to the Study:

The aim of this research is to evaluate the impact of project-based learning method on student engagement in the Six Sigma Green Belt Quality modules. The main aspects of engagement that will be studied are: learning effort, participation in class, communication, learning satisfaction, feeling of being supported by lecturer and peers, sense of belonging, learning passion, knowledge, perseverance and resilience in the face of challenges, use of deep strategies, self-regulation. The results of the study will form the basis of an improved teaching strategy for the Six Sigma Green Belt Quality module as well as other engineering modules.

Participant Declaration (Tick 'Yes' or 'No', as appropriate.)		
I have read or have had the information sheet read to me and I understand the contents.	**Yes**	**No**
I have been given an opportunity to ask questions and am satisfied with the answers.	**Yes**	**No**
I have given consent to take part in the study.	**Yes**	**No**
I understand that participation is voluntary and if I wish to withdraw I can do so within one month of initial participation.	**Yes**	**No**
I understand that withdrawal will not affect my access to services or legal rights.	**Yes**	**No**
I consent to possible publication of results.	**Yes**	**No**

I (the participant) give my permission for the data obtained from me to be used in other future studies without the need for additional consent.	**Yes**	**No**
Researcher Declaration (Tick 'Yes' or 'No', as appropriate.)		
I have explained the study to the participant.	**Yes**	**No**
I have answered questions put to me by the participant about the research.	**Yes**	**No**
I believe that the participant understands and is freely giving consent.	**Yes**	**No**

Participant Statement:

I have read or had read to me this consent form. I have had the opportunity to ask questions, and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights. I understand I may withdraw from the study within one month of participation. I have received a copy of this consent form.

Participant Name:

Contact Details:

Participant Signature: *(In the instance where a participant is under 18 years of age, a parent or guardian's signature is required.)*

Date:

Researcher Statement:

I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I offered to answer any questions and have fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

Researcher Signature: **Date:**

APPENDIX 4. OBSERVATION

GMIT
INSTITIÚID TEICNEOLAÍOCHTA NA GAILLIMHE-MAIGH EO
GALWAY-MAYO INSTITUTE OF TECHNOLOGY

School of
Engineering

Module: Six Sigma Green Belt Quality

Project 2: Root Cause Analysis

Observer:

Group:

Date:

Duration of observation:

Number of participants:

1. Context

Description of the session: the observation covered the complete session

Purpose of the session: work on Project 2 – Root Cause Analysis

Resources: materials on Moodle, internet

Ways the participant activities were structured: as pairs

Activities: analysis of data using Minitab, interpretation of writing project report

Comments: _____

2. Data collection

In this section the observer is documenting what occurred in the session.

Observation sheet – instantaneous sampling

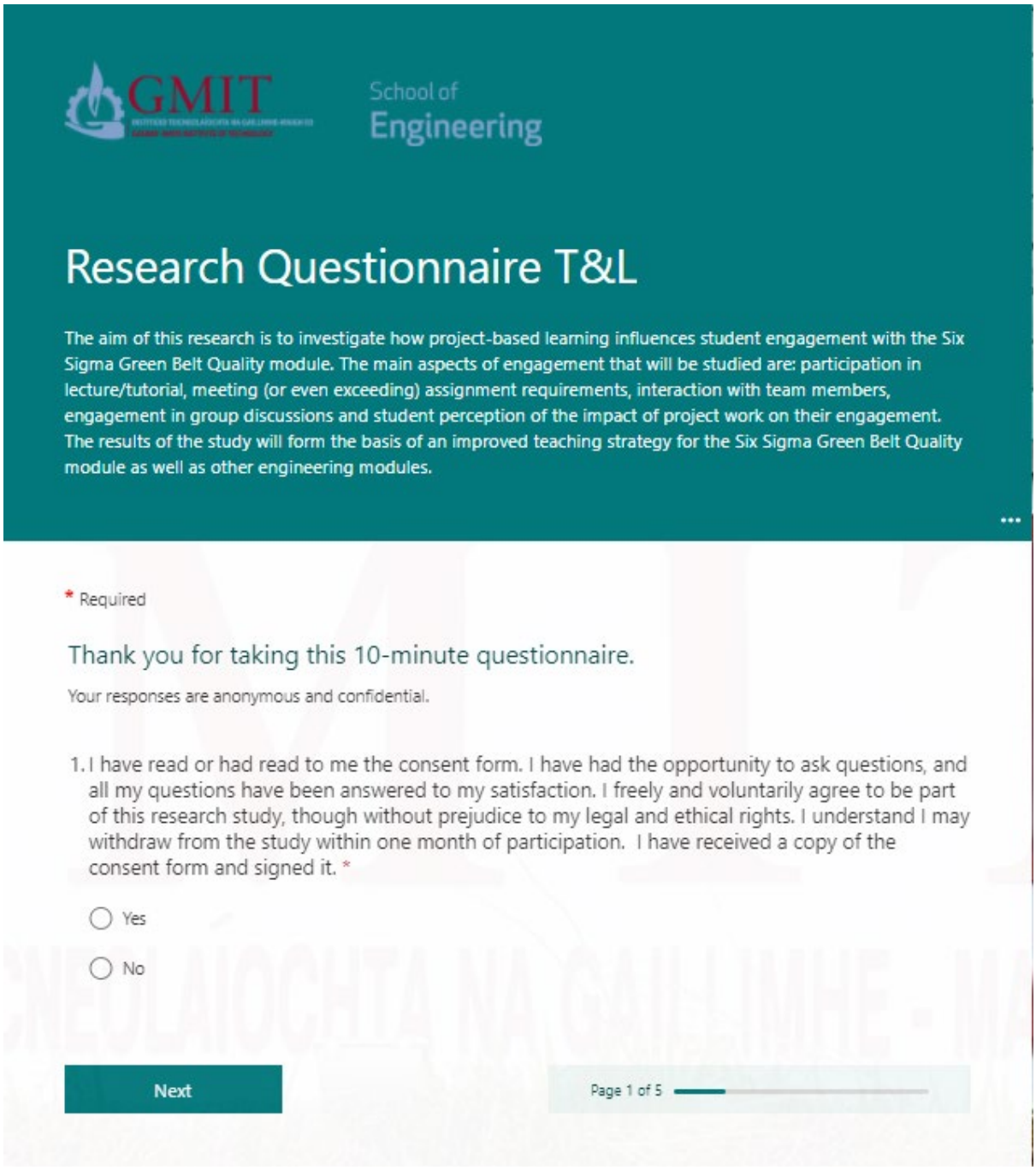
The observer notes what happens in the appropriate category each time she visits a breakout room. Sampling will take place at each visit, time will be recorded. Each student who signed the consent form will be observed.

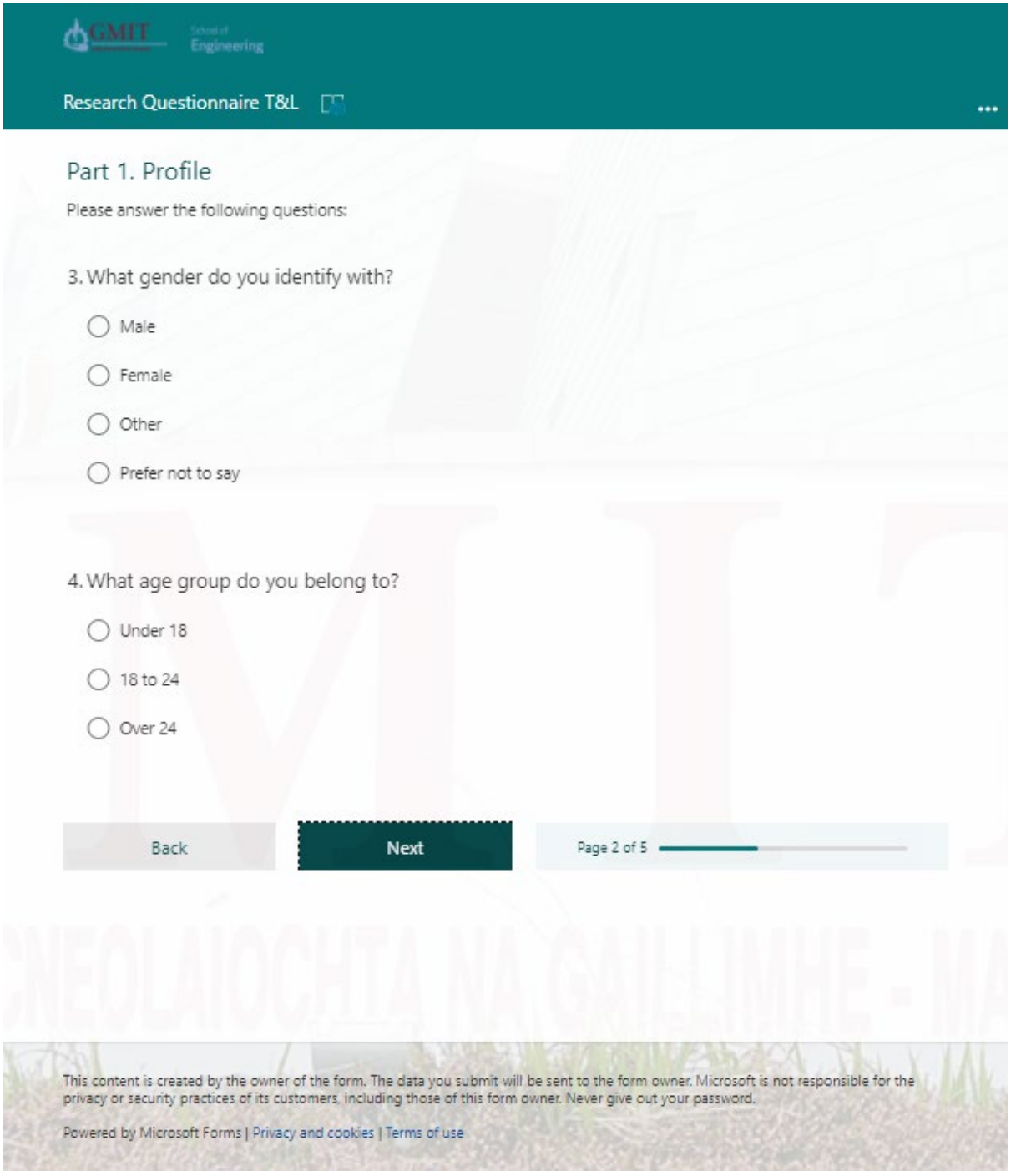
Coding:
Y = yes, N = no
V = verbal; C = chat box; E = email; S = screen sharing; O = other (specify in comments - could be Google docs or something else)
L = lecturer; S = student
On a scale of 1 to 5, 1 = not at all; 2 = very little; 3 = a little; 4 = a lot; 5 = a very great deal
+ is positive emotion, - is negative emotion
☑ = Occurrence

Observation domain	Observation focus	Incidence					Comments	Indicator
		Student 1	Student 2	Student 3	Student 4	Etc.		
Behavioural engagement	Student has already started working on the project before class (Y, N)							learning effort learning satisfaction
	Student discusses project-related issue with a peer (V, C, E, S, O)							communication feeling of being supported sense of belonging
	Student collaborates with another peer (from a different team) (V, C, E, S, O)							communication feeling of being supported sense of belonging

	Student asks a question (L, S)							participation in class feeling of being supported learning passion learning satisfaction
	Student answers a question (L, S)							participation in class communication sense of belonging
	Student discusses other topics, not related to the project (☑)							communication learning satisfaction learning passion
Emotional engagement	Student seems to show energetic involvement in discussion (e.g. excited speech) (☑)							learning satisfaction learning passion
	Student seems to express enjoyment (e.g. laughter) (☑)							learning satisfaction learning passion
	There is a long pause when I visit the room (boredom, working, something else?) (☑)							learning satisfaction learning passion
	Student uses emoticons (+, -)							learning passion
Cognitive engagement	Student is able to do the anaysis and interpret the results (1, 2, 3, 4, 5)							knowledge higher order thinking
	Student persists with seeking to understand data analysis (1, 2, 3, 4, 5)							perseverence self-regulation
	Student demonstrates self-regulated and independent learning (e.g. searching for additional info) (1, 2, 3, 4, 5)							self-regulation perseverence learning passion
	Student focuses on project work, didn't let himself/herself distracted (☑)							self-regulation learning passion learning satisfaction

APPENDIX 5. QUESTIONNAIRE




GMIT
School of Engineering
Research Questionnaire T&L
Part 1. Profile
Please answer the following questions:
3. What gender do you identify with?
Male
Female
Other
Prefer not to say
4. What age group do you belong to?
Under 18
18 to 24
Over 24
Back
Next
Page 2 of 5
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Research Questionnaire T&L ...

* Required

Part 2. Participation and interaction

Please answer the following questions:

5. I would evaluate my work on the project as follows: *

	Strongly agree	Agree	Neither Agree nor Disagree	Disagree	Strongly disagree
I had enough class support material (notes and other resources) to attempt the project in my own time before the project class.	○	○	○	○	○
I had enough knowledge before the class to attempt the project.	○	○	○	○	○
I tried to get as much feedback and guidance from the lecturer in class.	○	○	○	○	○
I implemented feedback immediately.	○	○	○	○	○
Project-based assessment takes more time than studying for a traditional assessment.	○	○	○	○	○
I found project work much harder than expected.	○	○	○	○	○
I couldn't do much work on the project in class.	○	○	○	○	○

6. During the class dedicated to the work on the project:
(Tick as many as appropriate) *

- [ ] I got actively involved in the data analysis process
- [ ] I listened to the lecturer's explanations and comments and applied them
- [ ] I asked questions
- [ ] I answered when the lecturer asked a question and I knew the answer
- [ ] I asked for help when I needed it
- [ ] I helped my colleagues when they needed help
- [ ] I didn't get much work done

7. Please explain your choices in question 6 *

Enter your answer

8. I found the best ways to communicate with lecturer:
(Tick as many as appropriate) *

- [ ] by email
- [ ] by Teams chat
- [ ] by posts on Moodle
- [ ] by submitting my work and getting feedback
- [ ] by face-to-face discussion

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GMIT School of Engineering

Research Questionnaire T&L ...

* Required

Part 3. Perception

Please answer the following questions:

9. While working on the project I felt:
(Tick as many as appropriate) *

- [ ] Enjoyment of learning
- [ ] Interest in learning
- [ ] Desire to learn
- [ ] Feelings of accomplishment
- [ ] Enthusiasm
- [ ] Curiosity
- [ ] Boredom
- [ ] Being overwhelmed
- [ ] Lack of interest
- [ ] None of the above

10. Please explain your choices in question 9. *

Enter your answer

11. How would you rate the following statements? *

	Strongly agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly disagree
I enjoyed the collaboration with my project partner.	○	○	○	○	○
I cooperated with other groups, not just my project partner.	○	○	○	○	○
I felt supported by my peers and lecturer while working on the project.	○	○	○	○	○
I felt part of a learning community.	○	○	○	○	○

12. Please detail on the aspects of the collaboration you liked/disliked. *

Enter your answer

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Part 4. Knowledge

Please answer the following questions:

13. The work on the project helped me: *

	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly disagree
Understand when to apply regression analysis to a real-world problem.	○	○	○	○	○
Understand when to apply hypothesis testing to a real-world problem.	○	○	○	○	○
Carry out successfully a regression analysis.	○	○	○	○	○
Carry out successfully hypothesis testing.	○	○	○	○	○
Interpret the results of a regression analysis in order to confirm (or not) the root cause of a problem.	○	○	○	○	○
Interpret the results of a hypothesis testing in order to confirm (or not) the root cause of a problem.	○	○	○	○	○
Make decisions or recommend measures based on root cause analysis.	○	○	○	○	○

14. I found the project challenging. *

- ○ Yes
- ○ No

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15. Can you give an example of challenge that you encountered? *

Enter your answer

16. Project-based learning helped me:
(Tick as many as appropriate) *

- [ ] Effectively organise my college work
- [ ] Manage my time better
- [ ] Understand what I know and where I have gaps
- [ ] Work independently
- [ ] Self-evaluate my performance
- [ ] Keeping up to date with work instead of letting it pile up until the end of the semester
- [ ] None of the above

17. Is there anything else that you would like to tell me about your learning experience based on project work? *

Enter your answer

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APPENDIX 6. EMAIL SENT TO POTENTIAL PARTICIPANTS TO INTERVIEW

Subject: participation to research

Hi XXX,

Thanks for your participation to my research regarding the topic of project-based teaching and learning. In the next step I'd like to clarify a few issues that came out of the survey and, as you seem to be comfortable online, I thought you might be interested in a short discussion. It will take around 20 to 30 minutes (max.) and will be organised on MS Teams, outside class hours.

I would really appreciate your contribution. I will reward your effort with a digital badge for contribution to research. It would be great if you could get back to me by… with a response.

Thanks,

Aurora

APPENDIX 7. INFORMED CONSENT FORM 2

RESEARCH PARTICIPANTS IN FOCUS GROUPS AND INTERVIEWS[1]

INFORMATION SHEET	
Purpose of the research study.	The aim of this research is to evaluate the impact of project-based learning method on student engagement in the Six Sigma Green Belt Quality modules. The main aspects of engagement that will be studied are: learning effort, participation in class, communication, learning satisfaction, feeling of being supported by lecturer and peers, sense of belonging, learning passion, knowledge, perseverance and resilience in the face of challenges, use of deep strategies, self-regulation. The results of the study will form the basis of an improved teaching strategy for the Six Sigma Green Belt Quality module as well as other engineering modules.
What the research study will involve.	The research study involves voluntary participation of students into: • Observational study (researcher observes student's behaviour during execution of a particular task) • Completing questionnaire • 1-to-1 interview. During the interview you do not have to do or answer anything you do not feel comfortable with, you can take breaks whenever you wish and you can leave at any time without penalty or loss.
Why you have been asked to take part in this research study.	You have been asked to take part in this research study as you have enrolled to the Six Sigma Green Belt Quality module. The module was chosen due to the practicality of the circumstances: you are timetabled in a computer laboratory, you have access to numerous sources of information (e.g. internet, GMIT library website) as well as dedicated software (e.g. Minitab, Excel), so it is properly set up for the purpose of the research.

[1] The document draws extensively on a work produced by Dr R. Swain of UCC, and is used with permission. Copyright is vested in same and all rights therein remain with Dr Swain.

The confidentiality of your participation in the research study.	The findings of the research study will be included in a final thesis report and publications. No identifying factors relating to you will be in evidence in the final thesis report and/or any disseminated research. Those who will have access to the research data include: the primary researcher, members of the Research Advisory Panel, internal examiners and external examiners.
What will happen to the information which you give.	Data collected/files will be securely stored on the researcher's passworded computer, according to GMIT security and data protection rules.
What will happen to the results.	The results of the study will be used for the MA thesis of the researcher and might be disseminated to larger audiences (lecturers in GMIT, conference, journal paper).
Are there any possible disadvantages of taking part?	There are no material risks, discomforts or side effects associated with this research. A possible disadvantage of taking part in a focus group or interview is giving up your time.
If a problem arises in relation to research participation.	If you wish to withdraw from this study, you are free to do so within one month of participation (without providing a reason). To withdraw, you should contact the principal researcher, Aurora Dimache who can be e-mailed at *aurora.dimache@gmit.ie*
Which body has reviewed this study from the perspective of ethical clearance?	The MA in Teaching and Learning Research Ethics Committee, GMIT.
Any further queries?	If you need any further information, you can contact me: Aurora Dimache *aurora.dimache@gmit.ie*
If you agree to take part in the study, please sign below.	

RESEARCH PARTICIPANTS IN FOCUS GROUPS AND INTERVIEWS

Date: **Signature(s):**

APPENDIX 8. INTERVIEW

GMIT
INSTITIÚID TEICNEOLAÍOCHTA NA GAILLIMHE-MAIGH EO
GALWAY-MAYO INSTITUTE OF TECHNOLOGY

School of
Engineering

Module: Six Sigma Green Belt Quality **Group:**

Date: **Time:**

Note taking and Teams recording begins, with prior permission.

A. Theme 1. Behavioural engagement

1. Compare your participation in class activity when you did project work vs. a normal class.

   Prompt: What learning activity did you engage in? How does this compare with traditional class learning activity? Did you ask questions? Did you answer questions? Did you work more? Did you get more done? Was project-based learning useful, beneficial? Would it be better to do the project totally outside class time, on your own?

   Probe: How? Why? Can you give me an example?

2. Compare study time for a traditional written CA (continuous assessment) vs. project work.

   Prompt: Did you study more for academic written assessments or for project-based assignments? Which one took more effort? Did you have to do a lot of work in your own time? Typically, how much study time is involved in a traditional written CA task? Typically, how much study time is involved in a PBL assignment task?

   Probe: How long? Why?

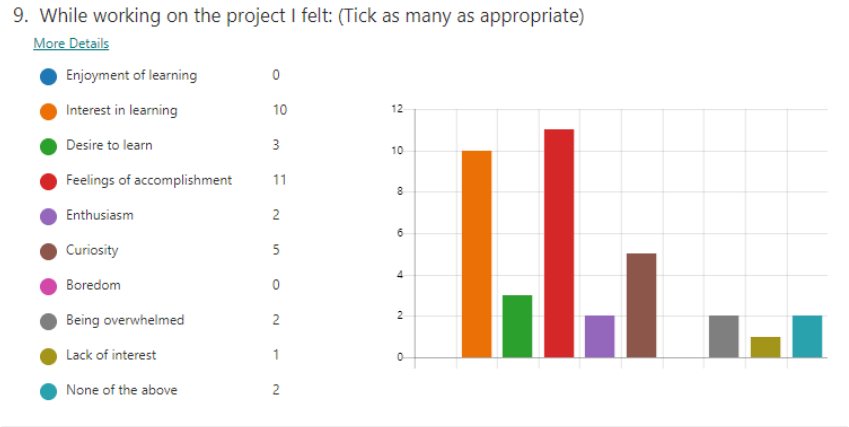
3. Did you collaborate with peers outside class time?

   Prompt: What platform did you use? What forms of collaboration were you involved in? (Did you collaborate with other classmates or just the project partner? Did you work on the same document?) Did you collaborate more than usual? How does online collaboration differ from classroom collaboration? Did the online collaboration pose any challenges?

   Probe: How? Can you give me an example?

B. Theme 2. Emotional engagement

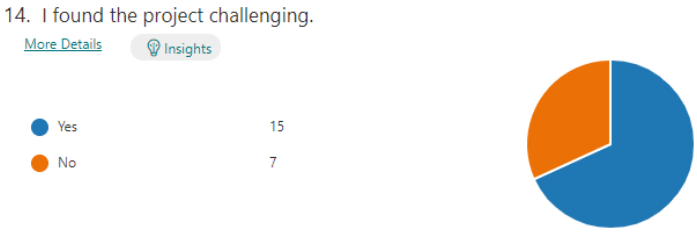
4. As this graph shows, nobody felt enjoyment of learning. What are your thoughts on enjoyment of learning?



Prompt: Did you have fun working on the project? Did you laugh when working with your peers? Was there joy when you mastered regression analysis or hypothesis testing? Any feelings of accomplishment? Any of those happy moments when you finally got it?

Probe: Why? When? Can you give me an example?

5. In general, students found the project challenging. Did you? Did you like being challenged?



Prompt: Did you find it motivating? Did you feel you were controlling your learning? Did it make you want to find more information?

Probe: Why? When? Can you give me an example?

6. Compare how motivated to learn you are in two cases: traditional written CA vs. project work.

Prompt: Did you feel more motivated to learn? What motivated you to learn? When did you feel most motivated? What are demotivators for this module?

Probe: Why? Can you give details?

C. Theme 3. Cognitive engagement

7. Why did the project work help you understand the theory behind regression and hypothesis testing?

   Prompt: Did the real-world problem helped? Linking theory to practice? Did the project work enabled you to gain a deeper understanding of probabilities and statistics?

   Probe: Why? How? Please detail.

8. Compare traditional learning (lecturer presenting slides and giving explanations, you trying to memorise and recall when needed) with project-based learning in terms of your capability to carry out the type of analyses required in the project (regression analysis, hypothesis testing)?

   Prompt: Did it help your capability to carry out the regression analysis, the hypothesis testing? Is it easier to learn this way than trying to memorise and recall?

   Probe: Why? Can you give an example?

9. How did the work on the project influence your capability of monitoring your activity and self-evaluating your performance?

   Prompt: Were you able to organise your work? To set goals and check if they were met and how well they were met? To identify what you know and what you don't? What you understand and what you don't?

   Probe: Why? Please detail.

D. Other aspects – improvement, challenges

10. What suggestions for improving the student learning experience based on project work do you have?

11. Any additional comments?

Session concluded. Audio recording stopped. Thanking for participation.

APPENDIX 9. DIGITAL BADGE FOR PARTICIPATION TO RESEARCH

Pick issuing organisation

Galway-Mayo Institute of Technology / Open Badge Training and Testing

RESEARCH CONTRIBUTOR

Galway-Mayo Institute of Technology / Open Badge Training and Testing

wayne.gibbons@gmit.ie

This sub-organisation is for training and testing Open Badges only.
This space is for training and testing-out the creation and issuing of badges during webinars/seminars/workshops.
Do not create a badge here that you intend to issue to a third party.

Tags: contributor, research.

This badge is awarded students who contributed to research at the Galway-Mayo Institute of Technology.

The earner of this badge made contributions to research within GMIT.

APPENDIX 10. TRANSCRIPT OF INTERVIEW WITH PARTICIPANT 2

A: I hope it works. Yesterday the internet connection was so bad, I don't know why. Today seems to be fine but I don't know. Normally it's perfect, but just yesterday I don't know what happened.

Participant 2: Yeah, you can get a bad day.

A: Yeah, I suppose. Yeah OK. So, first of all I want to thank you so much for doing this for me and second, I want to remind you that this is all confidential in the sense that nobody will have access to this recording. And when I write my report, I'm just gonna give a number to each participant, so it will be participant 1, 2, 3 and so on. Not even the initials, so nobody will be able to recognize anybody that participated to the study.

Participant 2: OK, that's perfect.

A: I just wanted to remind you that. Not to be worried about anything, you know? OK, so let's start 'cause I don't want to take too much of your time. Um, first of all, I'd like you to think about a normal classroom and the class dedicated to the project and in terms of your participation in class, how would you compare? What do you think?

Participant 2: Participation as in answering questions or…

A: Yeah, asking questions, answering questions, helping somebody else or trying to get help from somebody else. Anything like that. More work than usual or more to say or less...

Participant 2: Just in regards to working just in the group project, is it? Compared to being in? It's good now. Myself and XXX are living in the same house so it's a lot easier for us to talk and that. But with regards to online work, we can use the Microsoft Office so we can log on to the same file and edit it. We use that so we wouldn't have to be going to each other's bedrooms. We're working very well together, it's easy. None of us are slacking or holding back. Could you repeat the question again? As in?

A: Yeah, that actually answered another question of mine, so it's perfect.

Participant 2: Sorry, I was trying to figure out there, if you were asking comparing this to a classroom in person or…

A: I was thinking of the session that I organized dedicated just to the project. Remember when I broke you up into groups and sent you to breakout rooms?

Participant 2: Yes, yes, yes.

A: Then how was that compared to a normal session when it wasn't work on the project? It was something else. You know? Maybe I was presenting you some new section. I was doing things. Maybe then you were doing

things. So how would you compare your participation when it would be a normal class or that class which was only work on the project?

Participant 2: OK, sorry. So I think when it was just three of us in the little breakout room, it was easier for us to chat. And when you came in, it was a bit easier to ask questions. It could be like a little bit more, not daunting with everybody in the group, but a little bit harder to ask questions. Yes, that's all. That's how we feel about that.

A: OK, why? Why wouldn't you feel very comfortable when the others would be?

Participant 2: I'm not sure, to be honest. It's definitely just a mental thing. I don't know. But if I knew it could be just answering a question… with a question to ask I would have no problem asking, maybe just not 100% confidence in answering.

A: What if you were in class, let's say in a face to face class, how would that compare? I mean, it would still be loads of people, I mean the whole group in the class would. Would that make any difference?

Participant 2: If I was asked directly, I'd have no problem answering the question. But I feel if it was just left open to class,
I probably wouldn't put up, I don't know why that is. Just comparing this to last year, yeah.

A: I see. But the small group in the breakout room helps.

Participant 2: Yeah, for whatever reason, it's just easier to talk, yeah.

A: Very good. OK. What do you think about that session that I organized for working on the project only? Do you think it was good, helpful?

Participant 2: I do, yeah. 'cause I was thrown in with the other two guys, with XXX and XXX, so we were able to share ideas and it's kind of a different outlook on how we were working together. It was good, yeah. Found it helpful. I know for the Minitab and that it's easier in the class with everybody in it, but just for the project work, I think it was better to have the smaller group.

A: If I didn't organize a session, so I just continue as usual with classes and just give you the project to do outside class totally, so with no help, no possibility to ask questions or talk to each other and so on, just you and your partner, or, of course, you and the other students as well, but not in the classroom at all. Do you think that would be better or not?

Participant 2: No, I think it's better to be in the class. To a certain extent we keep working, but you'd pick up on other things if you were in the class, that you might not have thought to ask about. Yeah, that'll be. So I think it'd be better anyway to have the class.

A: Yeah, OK, OK. In terms of the amount of effort, let's say time that you put in a traditional assessment. So let's say written assessment.

You know very well 'cause you've done so many so far. So, let's say you need to prepare for a Six Sigma assessment, just a written assessment, you know. Probably I would tell you that you would have three questions from such and such sections, focus on those or whatever. How would you compare the study time and the effort for such an assessment with the work on a project?

Participant 2: If… Let's say… you probably put more time into work on a project, just it feels like it's more of an ongoing thing, whereas with an assessment you could leave it maybe hanging for a little while and leave it. But with a project it's easier just to be tipping away at all time, and seeing that you're getting somewhere as opposed to just studying and trying to get sections covered. Yeah, that's… yeah, I think it is easier to learn with the project, definitely, compared to just having to look at sheets. I know we don't have sheets, but look at the web pages and try and figure things out. Yeah.

A: OK. I know that you talked to the other guys that were in the breakout room with you at the time, but how about outside class? Would you have collaborated with anybody else except XXX who was your project partner?

Participant 2: No, just to say I'm living with two others as well that are doing the course, XXXX and XXX. XXX is not doing Six Sigma, just XXXX. We might have a chat, but we never went into depth about anything else. I was just talking to myself and XXX and the two lads that were there.

A: What if you were on site all the time? So, no COVID, no nothing. Do you think that would make you work with others more often? Or it wouldn't make much of a difference?

Participant 2: I don't think it would make too much of a difference. I know you'd probably meet people in the hallway and could chat to them, but I don't think I'd set up a specific time to go and work on it with someone else other than the partner.

A: OK. OK, we've already touched on the collaboration, you've already told me what you're using, what kind of tool you're using to work with your partner to share the documents. Now I want to share my screen for a second and have a quick look at this question. I put some answers there for this question 'While working on the project I felt' and there were different options there. And if you look at my chart here, there are two columns totally missing, which means nobody said 'enjoyment of learning' or 'boredom'. Now, I'm happy enough that nobody answered they were bored while working on the project, but what I would like to know is why you think nobody answered 'I felt enjoyment of learning' when I was working on the project. What's your opinion about that? What's your feeling about that?

Participant 2: When I was actually answering that, I was kind of caught between enjoyment, interest and feelings of… is it enthusiasm there? I was kind of caught between the trade in, I wasn't 100% on what the difference was between the three of them. Because if I'm interested in something, I'm enjoying it so…

A: OK, I see that. OK, well at the same time you could have picked all of them if you wanted to.

Participant 2: OK, fair enough, I probably missed, skipped over it then and just answered it. But that's yeah, that's how I feel about it anyway.

A: Yeah, OK, perfect. So it might be just a bit of confusion 'cause the terms might be pretty similar. That's what you are saying.

Participant 2: Yeah, yeah. That's how I feel about it anyway.

A: Yeah, that's very good. OK. How about… You know, when… so you said feelings of accomplishment… did you say that or?

Participant 2: Yeah, that was it. It was accomplishment I think I said. Is it the Red column? Can see it there now. Yeah yeah.

A: So you feel like… it's like when you're doing anything else: when you finally got it, you're happy enough… Is that how it feels when you work on the project or it doesn't matter much, it's just like any other task or…

Participant 2: No, when you get… it's the same with Minitab, like the tasks that we're doing along, and just in the project when you get a part of it done and you're sure it's right, you know, you feel accomplished then, you feel confident in handing it up.

A: OK, that's good. Oh, I stop sharing that's why you couldn't see it.

Participant 2: That's why I was asking you.

A: Sorry. And another question that I asked, let me see where it is… yeah, is this one: 'I found the project challenging' and 15 people said 'yes', so that's about 68% of the people and some other people said 'no'. How about you? Remember, I said it's anonymous so I don't know who answered what. I only have totals, you know, or I have actually what each person answered, but I don't know who that person was. It's all anonymous, anonymous, anonymous. I don't know. But how did you feel? Did you feel it was challenging?

Participant 2: I did to an extent. It wasn't extremely challenging 'cause we've gone over the material and we had it all there in front of us if we wanted to see it. But yeah, I would have ticked 'yes' for that; if I said 'no' that would mean it was perfect, I didn't have to look at anything, I didn't have to look at any notes or anything like that.

A: But what do you understand by challenging?

Participant 2: Challenging like that I had to actually work. It wasn't just relax, sitting there clicking buttons. I had to think about what I was putting down.

A: So it kind of forced you to work, to think about it.
It wasn't very straightforward.

Participant 2: Yeah, not completely straightforward, you just tick a box or whatever.

A: Was it challenging from other points of view as well?
I don't know, maybe the collaboration that was different with the others, or, I don't know, anything else - deadline or anything else.

Participant 2: No, honestly no. I don't think so, because myself and XXX work well together anyway. And all that. So that wasn't a challenge at all. No, the deadline was fine, plenty of time I feel to get it done anyway. So yeah.

A: OK. And, in general, do you like being challenged, and did you feel the same with this task?

Participant 2: In general, yeah, I would. I know it's grand to have it nice and easy, but you're not really learning unless you're getting challenged to solve it, so I think it's better. Yeah.

A: Very good. Again, comparing the traditional written assessment and assessment via project. In which case do you feel more motivated to learn?

Participant 2: I suppose… You'd be more motivated to learn probably I would say with the project, but for a normal assessment you're more motivated to study, if that makes sense. Yeah, so you'd be having to look into things going through a project whereas studying… you could just be
flying over something, thinking you understand it when you actually don't.

A: OK. So, it seems to be a difference, you said that yourself, between studying and learning. Learning means when after you've done something you've felt like you've learned something, and then if you need to apply it again, you would. Which one do you think is more 'learning' - when you work on a project or when you just study for an assessment? 'cause you're supposed to learn anyways, the assessment is supposed to basically make you learn, and, by doing the written assessment to still get something, you know. So that means you've learned. Which one do you think would be more useful and you get more learning, basically?

Participant 2: Definitely the project I'd feel you got more learning from. 'cause with study it feels like you're forcing yourself to do it whereas with the project it kind of just happens naturally when you have to go
through things yourself. And you get a better understanding as well.

A: OK, very good. Good. Was there a case that you needed to try to find more information when you were working on the project?

Participant 2: Um, I can't remember exactly what it was now, but we did have to google one or two bits. I can't remember exactly now, but it was one or two small bits, but most of what we needed was in the notes or we covered it.

A: OK, but you felt happy enough to just try to find things that you didn't find in the notes or it took too long maybe to find it or you were happy enough to just google it and try to find out what you needed.

Participant 2: Yeah, I'd look. I look at it. I wouldn't just take the first thing that will pop up, you have to actually look for it. But if it was something that was definitely correct, not off Wikipedia or something like that, then I'd be happy enough to use it.

A: What would motivate you to learn? And just relate to this module, which parts of it do you think are motivating enough and which ones are demotivating? If you know what I mean.

Participant 2: Do you mean like what? What topics we've been studying in it?

A: Topics or ways of doing things or…

Participant 2: Well, I found, say, with the Minitab, following along and then having to do the exercises afterwards, that's good. You'd be motivated to do that and 'cause it's interesting to see the graphs coming out and everything like that. Whereas, you know, if you just ran through examples and just let us off then it didn't have any exercises, people wouldn't listen to the lecturers or whatever. Yeah.

A: So anything that kind of forces you to do something you would be happy enough.

Participant 2: Yeah, yeah, exactly. I find it even with other modules. If there was just a lecture and there was not no context to it afterwards, then you kind of forget about it. Probably not great, but that's how I feel anyway.

A: Yeah, but doesn't matter if it's a software or if it's something else? So, let's say you might not need to do something necessarily in Minitab but still something to do. So let's say I would go through a few notes and then ask you to do something else, maybe a quiz, maybe just a little question that's not necessarily done in Minitab. Would that be the same?

Participant 2: Yeah, that would be the same, so anything that would make you apply what you're after doing. Yeah, if it was a quiz or written question, anything like that would be helpful, yeah.

A: Perfect. In terms of how you understood… you know, for the last project we applied regression analysis and hypothesis testing, those two things. In terms of understanding those analyses, how to do them, what you get from them, and so on… how do you think the project helped or did it help at all?

Participant 2: So, myself and XXX took parts in that XXX did the regression, which I kinda regret now because I feel like I missed out on doing the regression a small bit. But hypothesis testing definitely

helped back up what we were doing in class and so… yeah. I'd take it if we were doing again, I definitely would take a little bit of each to go over, definitely. We learned that anyway from the last one.

A: OK, OK. But how do you think that helped? How do you think the project helped you to understand better the hypothesis testing? (the part that you did yourself.)

Participant 2: Yeah, so it was just how to interpret the graphs I've just left to read over the notes now... We got 70 so I think we did OK. And how to interpret the graphs and the numbers that are in there, the key values and… I don't have anything in front of me, sorry. Yeah, it definitely did. It definitely help me understand better what you need to do and what you need to get out and talk about as opposed to just throwing the numbers in and getting out snips.

A: Good. And if I just kept talking about things and I didn't ask you to do anything… wouldn't help much…

Participant 2: No, I don't think so anyway. Maybe if it was just a short topic, you keep it in your head, but if you were moving through different things, I feel like, well, in my opinion anyway, I feel like I get kind of lost or having to track back over things if it wasn't being reinforced the whole time.

A: Perfect. Now, after doing the project, do you feel more confident that you would be capable to, as you were working mainly on the hypothesis testing, perform a hypothesis testing?

Participant 2: Yes, using Minitab, is it? Yeah. I would, definitely. Again, I'd have to just quick look over it again before I do it, but it definitely would come to me a lot easier than if I just had to go in before doing project and had to do it.

A: OK. Um, let me see what else I have here. How would you compare that with… let's say, I didn't give you a project, but still talking about hypothesis testing, still explaining what that is and doing some examples. How would you feel if at the end of the semester I would just give you the exam? No project in the meantime. Do you think it would be easier to just, you know, memorize things and then write down a question on hypothesis testing? Or the fact that you did a project as well would be a little bit better.

Participant 2: No, doing the project is definitely better than if we just had to learn as we went along and just jot them down then at the end and have to go back because just got a better understanding of it, having to apply it yourself and do it. I think that when I do anything like that, it just sticks better in my mind then.

A: Did it help the fact that we kind of worked on the project after a few weeks after we covered different aspects that were in the project?

Participant 2: It was, yeah it was fine that way. But we'd say… I know there wasn't too much content in it, but if the project was given earlier, let's say, and then you could be working away while you were doing the other topics… then it would probably… I don't know if it would be better or it could just make it drag out longer as well, so…

A: OK. Yeah, I see. And I've one last thing that I would like to ask you. In terms of your capability of self evaluating your work and monitoring your work so, you know, how independent you were, let's say and how you managed to figure out e.g. 'Oh yeah, I'm right here, definitely this is the right answer' or 'no, I am not sure here' and so on. Did the project work influence that in any way?

Participant 2: So just trust in what I was doing myself, is it?

A: In what you were doing, yeah, in your capability of managing your time and the project properly, to be sure that you deliver on time and, you know, and your self confidence. Yeah, I know what I'm doing and when you get an answer you feel that it's probably the right answer. Or, you know, that kind of stuff.

Participant 2: Yeah, the project would have backed that up and I did feel like I know I had to look at the notes and look up different parts, but I did know what I was doing at the same time. Yeah, so it was nice just to understand what was happening and…

A: How about the fact that you had to work with a partner on the project? Did that influence anything in any way? Compare to, let's say, you were working on your own.

Participant 2: The only thing will probably be, surely, you can't have everything your own way. Not like, say, if one person does something one way, you can't just barge in and say, well, that's not the way to do it; you have to compromise. But it's still good working with a partner because you can share ideas and it would help you building your own skills as well. If you're not quite as good at something, he's there, you can ask them to help you or to show you how to do something, yeah.

A: Did that partnership put any pressure on you in any way?

Participant 2: no, no, no it didn't. Not myself and XXX anyway. Maybe if I was with someone else it would have, but I was lucky enough.

A: OK, OK OK. I'd say that's all I wanted to ask you but I would also want to see if you have any suggestions at all regarding, I don't know, any improvement that I could bring to this module, related to project work or not.

Participant 2: You put me on the spot. The only thing that I found… now I know it's not a big deal, but… just going back through the notes and if you're trying to do something in Minitab, let's say if you didn't get it done in class – I know you could ask yourself - but if you wanted to redo something, I found it hard to follow just in the notes, if you wanted to do something in Minitab 'cause the steps aren't all there. But that's just something I noticed. Nothing else.

A: Yes, yeah, but you see, because I knew that I don't have that, at the very start, when we started using Minitab, I said when you solve the question just write, maybe just for the first question, the steps that you're doing there. So, go to Stats > DoE > etc., whatever, you know,
that kind of stuff, or maybe take a screenshot when all those windows are open so you know what you're doing. So, next time when you have to do it, you can go straight to the document that you already had with your work and could be easier…

Participant 2: But it's not about it here. I didn't even think of doing. That's sound, all right.

A: Yeah, I suppose, yeah, I can work on that… either maybe create some short videos to say this is where you need to go to Minitab to do what you need to do that particular type of analysis… Or just in the notes, just say click that, that, and that's it. Yeah, I can do that.

Participant 2: Yeah, I know it's not a big deal, but it would just make it a little bit handier and to navigate around, yeah.

A: And in terms of projects, would you have any suggestions?

Participant 2: The way you're doing the projects is good. Having a couple of small ones, but would there be much to do and make a year-long project or will there be any way you could do that?

A: Do you think that would be better?

Participant 2: I don't know about better, but it could be interesting to see having to bring everything in together and, you know, all the topics that we're learning. Bring them all in together in one big project, yeah.

A: I was thinking of that, actually. I wasn't sure how… you know… I obviously have to give you something from the very start, but if people don't do bits and pieces nearly all the time, it's all left to the end. That might be a little bit of a problem, so that's why I wasn't sure. But I suppose what I could do, I could divide it in parts and give you deadlines for each part, so at least something is done.

Participant 2: Yeah, definitely yeah. I know what you're saying, right? If there was just one deadline at the end, you probably get some terrible reports. People leave it till the last week to do it or something. Yeah, yeah, well, fair enough. Nothing else springing into mind now. No, I can't think of anything else.

A: That's great, thank you so much. What I will do, just to reward you for your half an hour that you stand here, of your time. I was thinking that I could just maybe give you a badge. You know how digital badges seem to be quite appreciated these days by employers, so maybe that would help, especially that it's different. You know, it's not like for whatever participating into normal classes and so on, it's something different.

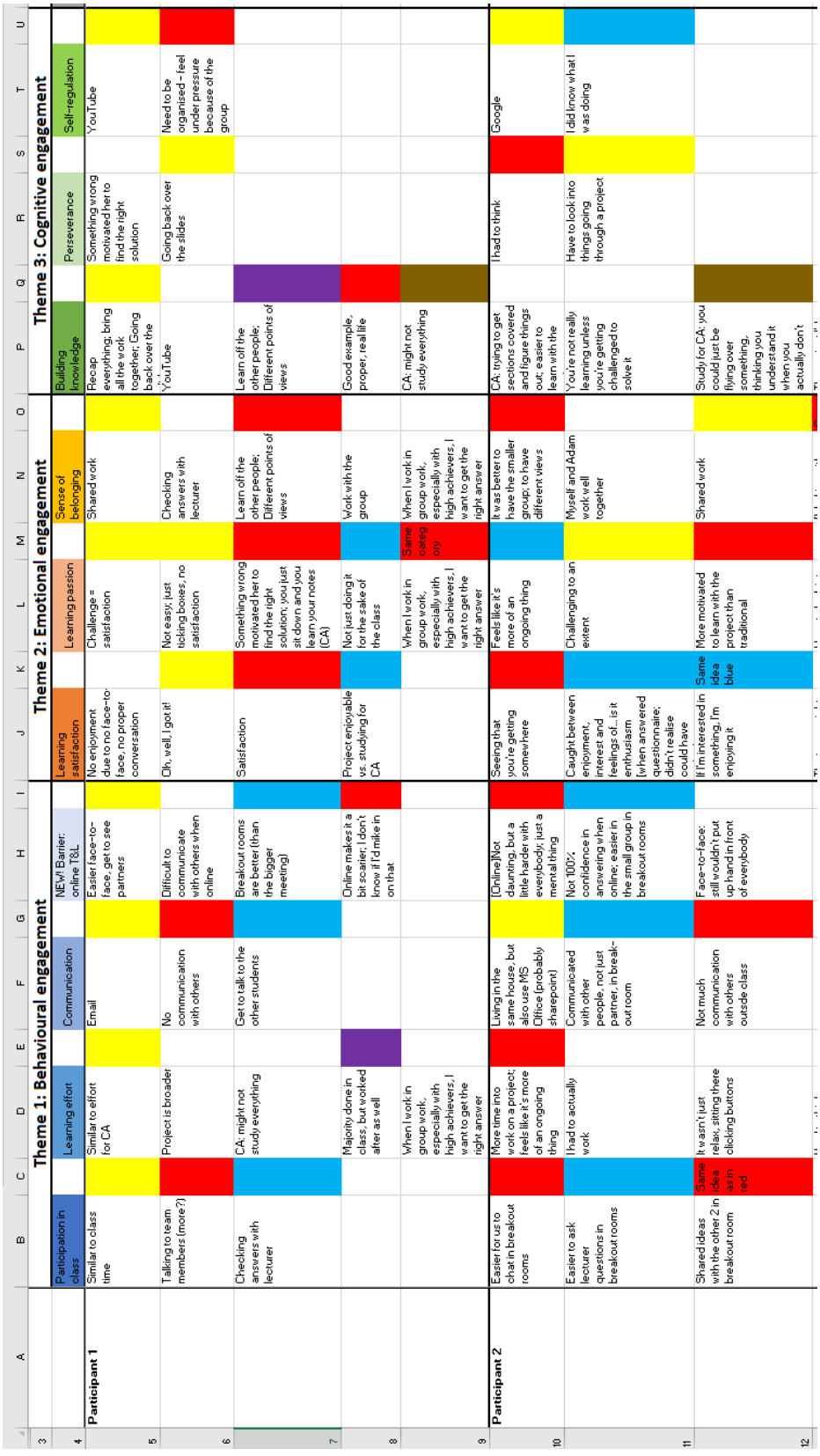
Participant 2: So yes, definitely, it would be great having it on the CV, yeah cheers thanks.

A: Thank you so much

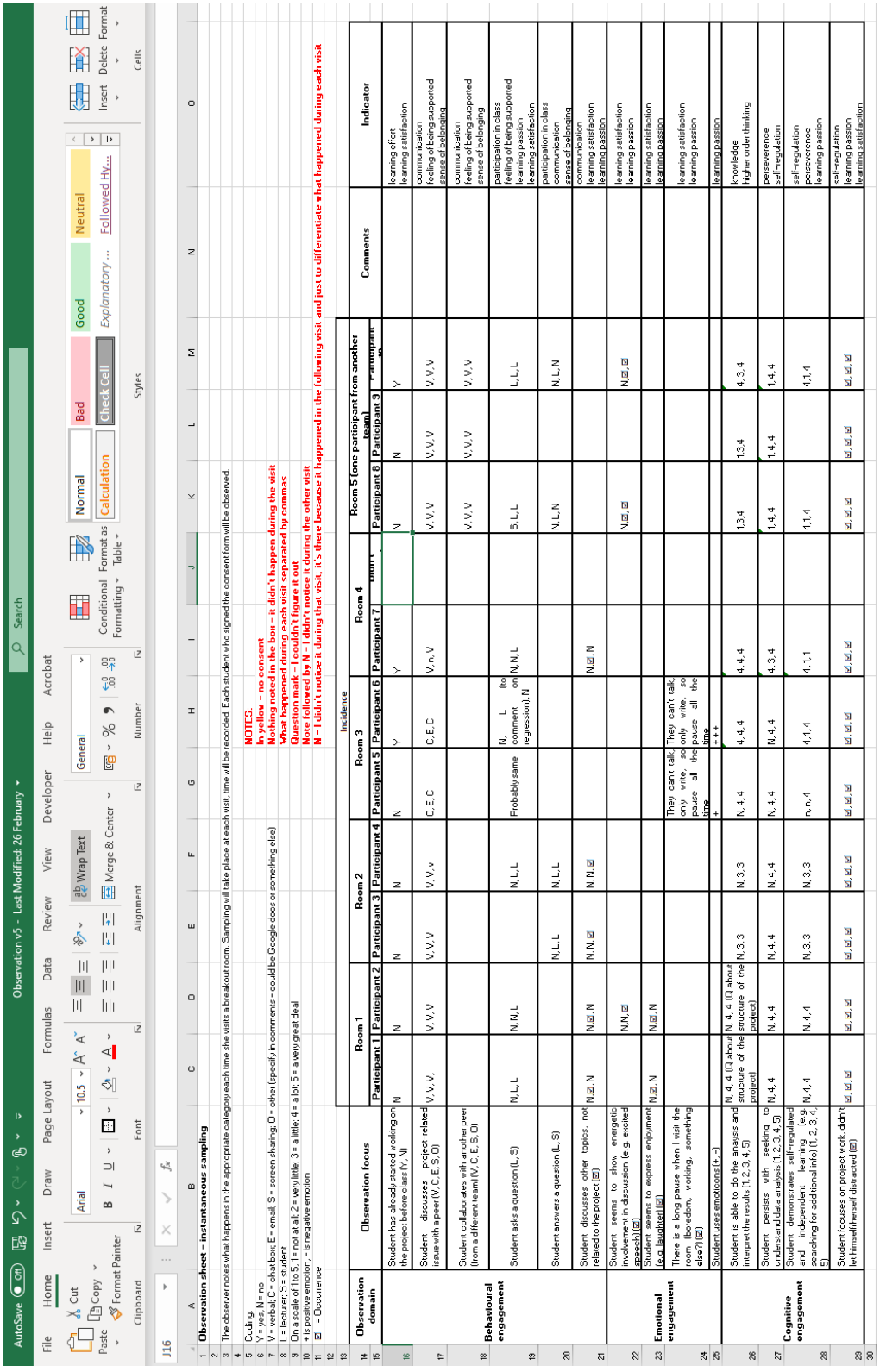
Participant 2: Thanks, bye.

A: Bye.

APPENDIX 11. SAMPLE OF COLOUR CODING OF QUALITATIVE DATA FROM INTERVIEW WITHIN SUBTHEME



APPENDIX 12. SAMPLE OF RAW DATA COLLECTED DURING OBSERVATION USING LETTER, NUMBER AND SYMBOL CODING IN EXCEL



APPENDIX 13. SAMPLE OF FREQUENCY ANALYSIS OF QUALITATIVE DATA FROM OBSERVATION USING LETTER, NUMBER AND SYMBOL CODING IN EXCEL