AN EVALUATION OF THE EFFECTS OF FLIPPED CLASSROOM PRE-LABORATORY ACTIVITIES ON STUDENTS' ENGAGEMENT WITH LABORATORY LEARNING: A HIGHER EDUCATION ACTION RESEARCH 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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DECLARATION OF ORIGINALITY

I declare that the material, which is submitted in this thesis towards the partial fulfilment of the requirements for the Master of Arts in Teaching & Learning, is entirely my own work and that all the sources have been acknowledged. This material has not been submitted for any other academic assessment other than the partial fulfilment of the above work.

ABSTRACT

A key goal of Institutes of Technology (IoTs) is to produce workplace-ready graduates who have the technical and practical skills to solve real world problems. Consequentially, the practical element of a module is a powerful learning environment for future graduates. Improving the laboratory learning environment and students' engagement, by embracing new technologies and adopting student-centred teaching strategies has become a focus area in educational research. Pre-laboratory activities (PLAs) have been identified as an area that with improvement can transform and enhance the practical learner experience. The aim of this research is to evaluate the effects that flipped classroom PLAs have on students' engagement with laboratory learning in Higher Education. The main objectives of this study are: to clarify key terminology relevant to this research; to critically evaluate existing literature relating to PLAs; to explore the learning theories underpinning PLAs; to evaluate students' engagement with the PLAs and finally, to analyse the research findings in conjunction with the literature to present recommendations for future practice. The research methodology employed is a mixed methods action research study. The scope is to evaluate students' and the lecturer-researcher's opinions of how the PLAs impact on student engagement for an introductory electronics module at AIT. It does not consider other groups, modules or institutes. The findings suggest that PLAs have a positive impact on student engagement in several areas such as attendance, collaboration, confidence, motivation and learning, but there are challenges to improving the engagement of some students. A notable conclusion is that PLAs are a worthwhile intervention in a module to improve student engagement and this is critical given the strong links between engagement, academic performance and student retention. Two key recommendations from this study are; 1) to ensure a maximum number of students avail of the benefits of PLAs, they should be linked to a summative assessment element in the module and 2) future research work should consider a strategy to gain deeper insights from those students who are not using the PLAs.

KEYWORDS: *student engagement; pre-laboratory activities; flipped classroom; action research; laboratory learning; higher education*

DEDICATION

To John, Cathal, Emily and Anna. Thanks for all your love and support throughout this process.

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LIST OF ABBREVIATIONS

AIT – Athlone Institute of Technology

AUSSE – Australasian Survey of Student Engagement

AR – Action Research

BEng - Bachelor of Engineering

CLT – Cognitive Load Theory

DkIT - Dundalk Institute of Technology

HE – Higher Education

HEI – Higher Education Institute

IoT – Institute of Technology

ISSE – Irish Survey of Student Education

ITC - Institute of Technology, Carlow

ITS - Institute of Technology, Sligo

PLAs – Pre-Laboratory Activities

TEAM - Technology Enhanced Assessment Methods

UDL – Universal Design for Learning

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CHAPTER 1 INTRODUCTION

1.1 Context

Producing workplace-ready graduates is a key goal of the Irish Higher Education Institutions (HEIs). In this context, the Irish Institute of Technology (IoT) sector places a particular focus on developing practical skills (Breen et al., 2017). The development of technical skills to solve real-world problems is essential to enhance student learning and employability (Abdulwahed & Nagy, 2008, p. 9). Therefore, the practical element of a module possesses the capacity to represent a powerful learning opportunity for future graduates (Hofstein & Lunetta, 2004). Advancing digital technologies are challenging both the pedagogical stance of traditional laboratory teaching and equally offering innovative opportunities for student learning at HEIs (O'Flaherty & Phillips, 2015, p. 86).

I am currently working as a lecturer in Athlone Institute of Technology (AIT), in the Department of Computer and Software Engineering, in the School of Engineering. Students attending this department in AIT come from diverse backgrounds; mature students, school leavers, local and international. While the importance of laboratory learning is clear - both from literature findings and based on my professional experience - teaching students in laboratories has many challenges (Feisel & Rosa, 2005). The different levels of understanding that each student brings to the laboratory has meant that a certain portion of students can become disengaged with the challenging content of laboratories (Brinson, 2015; Hofstein & Lunetta, 2004; Ma & Nickerson, 2006). In parallel with this, the literature indicates that one of the primary components of effective teaching is student engagement and that engagement is critical for learning (Coates, 2010; O'Flaherty & Phillips, 2015). The literature also shows clear links between student engagement and factors like student retention, student satisfaction and academic performance (Fredricks et al., 2004; Günüç & Kuzu, 2014; Kahu, 2013; Schindler et al., 2017; Zepke, 2014). This has led to an increased focus on the adoption of more active, student-centred teaching pedagogies that lead to deeper approaches to learning such as flipped classrooms for practical preparation (Bree, 2019; Loveys & Riggs, 2019, p. 65).

In line with the literature, pre-laboratory activities (PLAs) are defined as preparatory work students are required to do in-advance of a practical laboratory session (Bree, 2017). Literature on the use of PLAs, suggest that PLAs benefit learning and are worth incorporating, to improve any practical learning environment (Abdulwahed & Nagy, 2011; Agustian & Seery, 2017; Bree, 2017; Cann, 2016; Jones & Edwards, 2010; Loveys & Riggs, 2019; Van De Heyde & Siebrits, 2019; Whittle & Bickerdike, 2015). However, none of these studies address the specific context of first-year engineering students in AIT or evaluate the effectiveness of the PLAs used in this study to enhance student engagement. This research will address that gap. Building on previous studies and in order to enhance student engagement and develop more student-centred teaching practices, PLAs were added to a first-year introductory electronics module, Interface Electronics, as part of an undergraduate Bachelor of Engineering (BEng) in Computer Engineering and a BEng in Computer Engineering with Network Infrastructure in AIT. The PLAs designed specifically for this study and to meet the learning outcomes of the Interface Electronics module, involved watching a video and simulating a circuit, before attending the practical laboratory session (see Appendix 1). The interactive, on-line circuit simulation tool used is the freely available, web-based simulation platform, Tinkercad (Aasvik, 2018; Reyes, 2018; Tinkercad, 2019).

In summary, this research seeks to evaluate the effects of flipped classroom PLAs on students' engagement with laboratory learning in higher education (HE) (see section 1.2. This research will build upon the existing literature and it will provide further insights for the field of engineering and in particular, the teaching of electronics. Of key importance, the findings will also contribute towards informing educators on how best to design pre-laboratory preparation resources to improve student engagement and ultimately student learning.

1.2 Aims and Objectives

The aim of this research is to evaluate the effects of flipped classroom PLAs on students' engagement with laboratory learning, in the context of a HE Action Research (AR) study.

The main objectives of this study are:

- Objective 1: To clarify key terminology relevant to this research; student engagement, flipped classroom, PLAs and AR.
- Objective 2: To critically evaluate existing literature relating to a flipped classroom teaching strategy in the form of PLAs with a view to informing the research design and analysis.
- Objective 3: To explore the learning theories underpinning PLAs with a view to informing the design of the PLAs.
- Objective 4: To design and conduct cycle one of an AR study aimed at evaluating students' engagement with, and their perceptions of their engagement with, PLAs.
- Objective 5: To analyse the research findings, in conjunction with the literature, and present recommendations for the next iteration of the action research cycle.

1.3 Research Methodology

The chosen research philosophies underpinning this research are interpretivism, constructivism and pragmatism. Section 3.3 discusses the different philosophical assumptions and justifies the chosen approach. Interpretivism and constructivism view knowledge as being constructed by humans as they interpret the world and pragmatism embraces all approaches to understand the research problem. Interpretivism and constructivism closely aligns to the research objective, which seeks to collect participants' experiences of how the PLAs impact on their engagement with laboratory learning. The practical based nature of this research demands a pragmatic approach.

The chosen framework is a mixed methods AR study. Section 3.4 outlines the different styles of education research and it justifies the chosen method of AR. The primary aim of this research is to evaluate if the PLAs are an effective intervention to improve student engagement, in a module I teach, Interface Electronics. Therefore, I have the dual role of lecturer and researcher. Given the personal dimension and the intention to implement and evaluate a change, with a view to re-visiting this change, an AR study was deemed the best fit.

The chosen methodology is broadly mixed methods, but predominantly qualitative in nature as discussed in section 3.5. A mixed methods research choice supports the pragmatic approach to research and enables multiple sources of evidence for an in-depth and broad investigation. The data collection tools, discussed in section 3.6, include a questionnaire and a focus group involving participants taking the Interface Electronics module as part of their first year BEng in Computer Engineering course at AIT. Given that an AR methodology was selected, self-reflection using reflective journals was also an important data collection tool. Consequentially, throughout this thesis I will predominantly use the passive voice, but I will intentionally use "I" where it is necessary to situate myself and make my decision-making process clear.

1.4 Scope and Limitations

This research employs an AR study to evaluate the effect of PLAs on students' engagement with laboratory learning in a first-year electronics module in a BEng Computer Engineering degree at AIT. The scope of this research is to obtain students perceptions of how the implementation of a new teaching strategy, in the form of PLAs impact on their learning and their engagement with learning for the Interface Electronics module. I also reflect on the process and use my reflection journals to assist the interpretation and analysis of the findings to present recommendations for future practice. The case is bounded in this study and consequently, one of the limitations is it does not consider other groups, modules, disciplines or institutions. In addition, the average sample size over the four-week research period is small (n=24). Of the total students on the module (n=40), many agreed to participate (n=33) however, not all of those were in-attendance or participated over the four-week research period. The PLAs are aligned with the learning outcomes of the Interface Electronics module and therefore comparison with other program modules is not feasible. Another limitation of this study is time constraint; only one cycle of the action research process will be completed within the study timeframe, with recommendations provided for the next cycle.

1.5 Thesis Structure

This section introduces a brief outline of the remaining chapters. This thesis consists of six chapters. Chapter 2 reviews the literature relevant to student engagement, flipped classroom, PLAs and the learning theories under-pinning PLAs. Chapter 3 discusses the research methodology and both outlines and justifies the methods underpinning this study; student questionnaire, focus group and reflection journals. Chapter 4 presents the findings from the data collection tools. Chapter 5 discusses the findings, investigates the implications for practice and answers the research objectives posed in this chapter. Chapter 6 summarises, reflects and concludes the study by offering recommendations for the next cycle and future research.

CHAPTER 2 : LITERATURE ANALYSIS

2.1 Introduction

The aim of this chapter is to critically analyse the literature and to utilise this existing knowledge as a foundation to build-upon and inform the research aim, which is to evaluate the effects of flipped classroom PLAs on students' engagement with laboratory learning, in a HEI electronics module.

Section 2.2 outlines the literature analysis methodology. The literature analysis will focus on three key areas meeting Objective 1, 2 and 3 shown in section 1.2. Firstly, in section 2.3, the concept of student engagement is reviewed, including a rationale for the definition used to evaluate student engagement for the electronics module supporting Objective 1. Next, in section 2.4, the concept of flipped learning is discussed and the benefits and challenges of a flipped learning strategy - in the form of PLAs - are critically reviewed supporting Objective 1 and 2. Finally, in section 2.5, a range of pedagogical theories underpinning the implementation of PLAs is critically evaluated supporting Objective 3. The recommended guidelines are explored to understand how they ensure the design and delivery of the PLAs is underpinned by a strong pedagogical framework.

2.2 Literature Analysis Methodology

The literature analysis was initiated by conducting a broad search for peer-reviewed articles published in the last five years, from 2014 to 2019, using the AIT library search engine. Several databases were consulted, including Academic Search Complete, ScienceDirect, IEEE Explore, Google Scholar and UK & Ireland Reference Centre. These databases include the top ranked journals in the fields of Education and E-Learning. They include but are not limited to: *Review of Education Research, Internet and Higher Education, Computers and Education, British Journal of Education Technology* and *Journal of Engineering Education* (Scimago Lab, 2019). The Research@THEA open access repository, containing research from all the IOTs was also searched, to capture conference proceedings.

Using the Advanced and Boolean Search, the search terms ‘student engagement’ AND ‘higher education’ AND ‘flipped’* were used to find key literature. The initial search revealed themes such as the theoretical perspectives on student engagement and implementation of flipped classrooms. However, they did not address the subject of enhancing student engagement in the context of laboratory learning. This led to more targeted searches of the same databases using specific keywords such as ‘lab’* AND ‘flipped’*. These articles were manually searched by accessing the relevance of the Title and Abstract to the research question. Key pieces of literature were identified, and their references were also reviewed. These studies highlighted the themes of pre-practical and pre-laboratory preparation - as a means to enhance student engagement - and the learning theories underpinning them as a suitable foundation for research (Abdulwahed & Nagy, 2011; Agustian & Seery, 2017; Bree, 2017; Cann, 2016; Jones & Edwards, 2010; Loveys & Riggs, 2019; Van De Heyde & Siebrits, 2019; Whittle & Bickerdike, 2015). This thesis contributes to the existing body of research from the aforementioned scholars. The next section defines student engagement and suggest a framework to measure student engagement for this study.

2.3 What is Student Engagement?

There are many different definitions of student engagement found in the literature. It is a broad and complex phenomenon for which there are many definitions grounded in psychological, social and cultural perspectives (Kahu, 2013; Schindler, Burkholder, Morad, & Marsh, 2017; Wimpenny & Savin-Baden, 2013). In its most immediate sense, student engagement refers to the contribution that students make towards their learning, as with their time, commitment and resources (Coates, 2010; Krause, 2005). More broadly, though, a review by Trowler (2010, p. 3) defined student engagement as a process involving both the student and the institution:

> The interaction between the time, effort and other relevant resources invested by both students and their institutions intended to optimize the student experience and enhance the learning outcomes and development of students and the performance, and reputation of the institution.

Similarly, the Irish Survey of Student Engagement (ISSE) website indicates student engagement reflects two key elements. The first is the amount of time students invest in their studies and other educational activities. The second is how institutions use resources and organise curriculum to encourage students to partake in activities to support learning (ISSE, 2018, p. 5).

Some authors have considered its antithesis. Krause lists “inertia, apathy, disillusionment or engagement in other pursuits” (2005, p. 4), while Mann contrasted engagement with “alienation” (2001, p. 7). Others question whether the use of the term is clear and consistent. Vuori (2014, p. 571) suggests a blurring between the terms student engagement and community engagement and he notes the concept is easily mixed up with student involvement. According to Kahu (2013, p. 768), viewing student engagement as a psycho-social process, influenced by institutional and personal factors and embedded within a wider social context, provides a deep and rich understanding of the student experience. Furthermore, it is argued these factors are not true indicators of student engagement (Schindler et al., 2017, p. 5). This view is also advocated by Axelson & Flick (2010, p. 42);

> But if we define engagement in the more limited sense—i.e., student involvement in a learning process—we can move past the issue of who is responsible to a more productive question.... That is, we might ask, “How do we engage (cognitively, behaviourally, and/or emotionally) *type X* students most effectively in *type Y* learning processes/contexts so that they will attain *knowledge, skill, or disposition Z*?”

Reflecting the concerns voiced by Axelson & Flick, this research study defines student engagement as student involvement in the learning process. It did not evaluate the role of external factors, like department or campus environment, on students’ engagement. This closely mirrors the research aim, discussed in section 1.2, which evaluates how a change in teaching strategy effects students’ engagement and involvement with their learning environment. Section 2.3.1 gives further insight into the theoretical perspectives and the importance of student engagement within the context of HEIs.

2.3.1 Theoretical Perspectives on Student Engagement

Student engagement has enjoyed considerable attention in literature since the mid-1990s, with the meaning of the construct evolving over time; it has strong roots in Astin’s (1984) influential work on student involvement (Kuh, 2009, p. 6). Student engagement has become a focus of attention to those aiming to enhance learning and teaching in HEIs. This is understandable given the clear links established, by a sound body of literature, between the engagement of students and variables such as student retention, academic performance, satisfaction and student resilience and persistence (Kuh, 2003; Pascarella, Seifert, & Blaich, 2010; Wimpenny & Savin-Baden, 2013, p. p.14).

The widespread use of student engagement surveys like the ISSE in Ireland - which is based on the National Survey of Student Engagement (NSSE) in the USA and Canada and the Australasian Survey of Student Engagement (AUSSE) in Australia and New Zealand - has helped reinforce this concept in the higher education domain. Findings from these studies highlight the relevance of engagement as an indicator of student performance and institutional performance (Coates, 2010; Kuh, 2009). The importance of student engagement is reinforced with the growing emphasis on accountability and the economic pressures on institutions to attract and retain students while ensuring they acquire the necessary skills to be successful graduates. Furthermore, student engagement has received more attention due to the shift towards student-centred, constructivist teaching pedagogies (Schindler et al., 2017, p. 3). Section 2.3.2 gives further details on how student engagement is evaluated in this study.

2.3.2 Measuring Student Engagement

Fredricks, Blumenfeld & Paris (2004, pp. 63-65) suggest there are three types of engagement: Behavioural, Emotional and Cognitive. Schindler et al. (2017) propose a conceptual framework using these three distinct types of engagement and the model indicates they are interconnected and mutually supportive. This model also outlines the indicators of each type of engagement. This is shown in Table 2.1.

Table 2.1 Themes and Indicators of Student Engagement
(Schindler et al., 2017, p. 5)

Student Engagement	
Themes	**Indicators**
Behavioural	Participation
	Interaction
Emotional	Interests and value
	Sense of belonging
Cognitive	Motivation
	Persistence
	Deep processing of information

Behavioural engagement is the degree to which students are actively involved in learning activities and it is the most common indicator used in engagement studies as it is the most observable and measurable indicator (Fredricks et al., 2004; Günüç & Kuzu, 2014; Kahu, 2013; Schindler et al., 2017; Zepke, 2014). Indicators of behavioural engagement include time and effort spent participating in learning activities and interaction with peers, faculty, and staff (Coates, 2010; Kahu, 2013; Kuh, 2009; Schindler et al., 2017; Trowler, 2010). Displays of positive behavioural engagement include asking questions, attendance and taking an active part in classes, paying attention and making efforts (Gunuc & Kuzu, 2015, p. 590).

Emotional engagement refers to student emotional reactions to learning and indicators of positive emotional engagement include interest and value towards learning (Fredricks et al., 2004; Trowler, 2010; Wimpenny & Savin-Baden, 2013). Indications of emotional disengagement are emotions like boredom and anxiety (Gunuc & Kuzu, 2015; Reeve, 2013). Feeling a sense of belonging and enjoying being part of a class and group is also considered within the scope of emotional engagement (Fredricks et al., 2004; Kahu, 2013; Trowler, 2010). In a study by Wimpenny & Savin-Baden (2013, p. 21), they found that “engagement as resilience has emerged as a powerful theme” and students illustrated an ability to engage despite dealing with alienation, lack of relevance and even the drudgery of study. Emotional engagement is often assessed using self-report measures and provides insight into how students feel about a particular topic, delivery method or instructor (Fredricks et al., 2004).

Finally, cognitive engagement is the degree to which students approach learning and expend mental effort to comprehend and master content (Fredricks et al., 2004; Schindler et al., 2017). Indicators of cognitive engagement include: motivation to learn, persistence to overcome challenges and deep processing of information through critical thinking, self-regulation and active construction of knowledge (Schindler et al., 2017). This deep learning is in contrast to surface learning, which is limited to memorization, recall and rehearsal (Reeve, 2013, p. 579).

In Schindler et al. (2017), the conceptual framework for measuring student engagement is student-centred, focusing exclusively on student-focused indicators rather than combining student indicators with confounding variables, such as curriculum design, department behaviours and campus environment (Schindler et al., 2017, p. 5). This framework closely aligns to a constructivist student-centred teaching pedagogy, whereby knowledge is constructed by those as they engage and interpret the world and by building on previous experiences. See section 2.5 for further discussions on constructivism. Schindler et al.'s framework influences the data-gathering tools used to measure student engagement in this AR study. This is discussed further in Chapter 3. In the next section, the flipped classroom teaching strategy and the use of PLAs is discussed.

2.4 Flipped Classroom and Pre-Laboratory Activities

The flipped classroom is broadly defined as a set of pedagogical approaches that move information-transmission teaching out of class, use class time for active and social learning, and require students to complete pre- and/or post-class activities to fully benefit from in-class work (Abeysekera & Dawson, 2015, p. 3). It was first popularised in secondary education in the United States (Bergmann & Sams, 2009). It is based on a vast array of different implementations, both with respect to out-of-class and in-class activities. This can be seen by the number of asynchronous resources utilised across various disciplines for pre-class flipped classroom preparation, which included pre-recorded lectures, pre-readings, automated tutoring systems and study guides, case-based presentations and simulations (O'Flaherty & Phillips, 2015, p. 87). These are then blended with in-class active learning, designed to create meaningful student-teacher and student-student interactions (Steen-Utheim

& Foldnes, 2018, p. 307). The flipped classroom is a rapidly growing area of research, but Abeysekera and Dawson (2015, p. 2) claim the flipped classroom approach is “under-evaluated, under-theorized and under-researched in general”. In a study of flipped classroom research based on 20 articles from 2013–2015, Zainuddin & Halili (2016, p. 325) found a number of positive impacts in flipped learning practice: students’ achievement, students’ motivation, students’ engagement and students’ interaction.

An evolution of the flipped classroom that has gathered pace in recent years is in the area of pre-practical preparations i.e., preparatory work students are required to carry-out in-advance of a practical laboratory session (Bree, 2019, p. 21). Of relevance to this study, is research that was conducted using online resources to prepare PLAs for a practical laboratory element. Selected key authors, their location and the field of interest are listed in Table 2.2.

Table 2.2 Research Studies on PLAs

Authors	Year	Location	Discipline/Course	PLAs
Loveys & Riggs	2019	Australia	Science - Biochemistry, Microbiology	Live video demos, animations, videos, MCQs (interactivity key focus)
Van De Heyde & Siebrits	2019	South Africa	Science- Physics	Video, simulation, pre-lab quiz
Agustian & Seery	2017	UK	Science - Chemistry	Pre-lab quiz, technique videos, interactive simulations
Bree	2017	Ireland	Science - Bioscience	Video and quiz.
Cann	2016	UK	Science - Biology	On-line quiz
Whittle & Bickerdike	2015	UK	Science - Biology	Multi-media resources (videos to demo, photographs), questions
Abdulwahed & Nagy	2011	UK	Engineering- Process Control	Simulated lab, pre-lab test
Jones & Edwards	2010	Australia	Science - Biology	Multi-media presentations

As can be seen from the table, these studies were conducted in several different countries and are mainly in the area of science. The PLAs include a wide array of different resources with many using videos and quizzes. Overall, the findings from these studies suggest that the PLAs are beneficial to learning. The next section presents a critical review of these studies and others, researching PLAs.

2.4.1 Benefits of Pre-Laboratory Activities

The literature suggests there are many benefits to PLAs. Of interest in the Irish HE context, is a report on *Embracing alternative formats, assessment strategies and digital technologies to revitalise practical sessions in Science & Health* (2019) by The Technology Enhanced Assessment Methods (TEAM) project led by Dundalk Institute of Technology (DkIT) partnering with AIT, Institute of Technology, Carlow (ITC) and Institute of Technology, Sligo (ITS). It identified pre-practical resources as one of five thematic areas, which with improvement can transform and enhance the practical learner experience. Bree (2019, p.22) states that, implementing PLAs "in any discipline represents a positive and engaging approach to motivate and focus students, while assisting them to perform better in practical sessions, stimulating learning and understanding overall". Bree (2017) carried out a study whereby he added pre-laboratory preparation videos to a molecular bioscience module and 39 second year students from DkIT, took part. The results of the research found students had a clearer and improved understanding of the experimental concept being examined compared to previous years where the preparation relied on reading the laboratory manual text.

Agustian and Seery (2017) summarise findings of sixty reports that describe pre-laboratory activity in HE chemistry. A synopsis of the findings shows that there are three focus areas for the PLAs: 1) experimental procedures, 2) conceptual understanding, and 3) affective dimensions – learner confidence and motivation. The main findings of their review indicate PLAs have a positive impact on learning in the laboratory. This is supported by Whittle and Bickerdike (2015), who also found engagement with preparation tasks, had a positive effect on student performance in practical modules. Students' test scores showed a significant difference among the performances of highly engaged, engaged and poorly engaged students, with higher engagement leading to improved performance.

This improvement in performance was also found in a comprehensive study carried out by Loveys and Riggs (2019) with 231 students over three years in two undergraduate science courses. Their study utilises principles of Bloom's Taxonomy (Bloom, 1956) to frame the learning activities that occur pre-, in- and post-class. The PLAs targeted the lower levels of Bloom's Taxonomy, 'Remember and Understand', by including definitions of discipline-specific terms (remember) or watching videos of techniques (understand). The in-class laboratory activities targeted the higher levels of Bloom's Taxonomy (Apply, Analyse, Synthesise and Create) where students had to apply their knowledge to design and perform experiments to synthesise data which could be analysed for an assessment task such as a report. The results of this study indicate that students not only felt better prepared for practical laboratory classes but also that their performance in assessment tasks for the practical classes improved after the introduction of interactive, online PLAs. The resources included multimedia videos and quizzes, with interactivity being a key feature. These results are supported by a statistically robust quantitative analysis of students' practical marks and questionnaires and qualitative student comments.

Improved confidence was another benefit of using PLAs. Whittle and Bickerdike (2015) sought students' opinions on the effectiveness of preparation material using questionnaires and many students reported that they found the preparation resources had increased their confidence in practical classes. These results confirm similar findings by Cann (2016) that show that even relatively simple online interventions can increase student engagement in practical contexts. Cann (2016) carried out a case study on a large cohort of students (n=182), the aim of which was to gain maximum educational benefit from minimum input. This is in contrast to the trend to develop sophisticated virtual laboratories that require significant investment and/or specialist skills (Cann, 2016, p. 102). Engagement with and results of online quizzes were analysed and student feedback via anonymous questionnaires was collected. Results showed that the majority of students readily engage with online quizzes without the driver of assessment. Of note is that by the end of their first semester this engagement has waned, but the engagement with PLAs can be rekindled by utilisation of minimal summative assessment.

The findings from the above studies using PLAs support the idea that teaching students who are better prepared for class encourages active learning and student engagement. As the studies suggest, this leads to greater student satisfaction and better learning outcomes (Loveys & Riggs, 2019; Whittle & Bickerdike, 2015). The next section discusses some of the challenges highlighted in the literature.

2.4.2 Challenges of Pre-Laboratory Activities

There are challenges and problems that must be faced by the lecturer to promote active learning as a means of enhancing student engagement in a flipped learning environment. As outlined by Hake (1998), cited in Van De Heyde and Siebrits (2019, p. 187), it is important to emphasise that online resources are not a “magic bullet” and there are many challenges. In contrast to many studies, according to a comprehensive scoping review of 28 studies by O’Flaherty and Philips on the flipped classroom, very few studies demonstrate robust evidence to support that the flipped learning approach is more effective than conventional methods. Only one report used empirical data to show evidence that the flipped classroom could effectively engage students in deep learning compared to traditional classrooms (O'Flaherty & Phillips, 2015, p. 94). Nevertheless, O'Flaherty and Phillips (2015, p. 94) conclude that teaching approaches that go beyond the traditional lecture are the most effective to engage students in learning.

Carefully designed pre-class learning approaches can successfully motivate students to complete pre-class activities that prepare them for in-class learning. These activities need to be short, interactive and focused on key concepts (Karanicolas et al., 2016, p. 314). They should also be embedded in the overall laboratory learning process (Agustian & Seery, 2017). This is supported by reports that indicate students will not engage with PLAs if they do not consider them of value and some students will need motivation in the form of summative assessment to focus attention on engaging (Cann, 2016).

Van De Heyde and Siebrits (2019) conducted an exploratory study to investigate students’ perceptions of online resources to prepare them for physical laboratories, compared to traditional pen and paper methods. While the results indicated that students felt better prepared for the laboratories using the online resources compared to traditional methods, another question highlights that over half the students are unsure or disagree that the online resources – video, simulation, pre-laboratory quiz - prepared them for the laboratory work. This may indicate that while students have access to additional resources, the demands of the laboratory session are still a challenge for students. Another challenge for lecturers, as highlighted by O'Flaherty and Philips (2015, p. 94), is a lack of pedagogical understanding of how to effectively translate the flipped classroom concept into practice, with the aim to engage students. The next section investigates the learning theories underpinning PLAs and the frameworks used to guide the design.

2.5 Learning Theories Underpinning Pre-Laboratory Activities

The success of learning activities depends on sound learning theory (Van De Heyde & Siebrits, 2019, p. 173). This section reviews the literature to show how PLAs are grounded in a strong pedagogical framework. It analyses constructivist learning style theory and Cognitive Load Theory (CLT) and explores how these theories can support the design and delivery of PLAs. It outlines the key recommendations to ensure that the design of PLAs is underpinned by these strong pedagogical frameworks.

2.5.1 Constructivist Approach

Constructivism is a learning theory based on people constructing their own meaning by building on previous knowledge and experience (Carlile & Jordan, 2005, p. 19). Piaget (1896-1980), one of the founders of constructivism theory, suggests that humans cannot be given information which they immediately understand and use; instead humans must construct their own knowledge (Blake & Pope, 2008). Consequentially, it rejects the traditional mode of transmitting knowledge from teacher to student. According to Dewey's influential work (1859-1952), active participation and self-direction by students are critical to promote meaningful learning (Hickman & Alexander, 1998). This reflects Bruner's (1978) view of constructivism that learning is an active process and knowledge is constructed based on pre-existing knowledge and experience.

To support a constructivist epistemology, teachers must guide and facilitate students to become active learners (not passive), by encouraging students to question, challenge and draw their own opinions and conclusions (Ültanır, 2012, p. 195). Constructivism, as a theory of learning, promotes a shift towards more student-centred teaching and self-directed learning using strategies like PLAs. The importance of PLAs to scaffold knowledge and foster independent learning cannot be overstated, as Chittleborough, Treagust and Mocerino (2007, p. 884) argue, "the importance of pre-laboratory preparation is crucial considering that what students already know determines what they will learn".

While Piaget's theory focuses on the individual, Vygotsky believed the learner constructed his or her own knowledge by interacting with other individuals (Blake & Pope p.60). Social constructivism stresses the need for collaboration among learners and teachers, as dialogue stimulates further thinking (Fosnot & Perry, 1996, p. 34). For Vygotsky, socio-cultural development occurs in the so-called "zone of proximal development", where learning happens through problem-solving under teacher guidance or in collaboration with more capable peers (Matusov & Hayes, 2000, p. 219). The practical laboratory environment facilitates social constructivism as it provides an excellent opportunity for students to work collaboratively and learn from each other. Facilitating learners to gain first-hand experience of their ability to solve problems - by doing the PLAs in advance of the practical session - leads to feelings of competence and belief in their potential to solve new problems (Prawat & Floden, 1994). Of particular significance for the objectives of this research, is Von Glasersfeld's (1998) assumption that motivation to learn is strongly dependent on the learner's confidence in his or her potential for learning. The next sub-section explores learning style theory.

2.5.2 Learning Style Theory

Another underlying principle of constructivism is its stress on diversity in learning (Carlile & Jordan, 2005, pp. 19-20). This diversity in students' learning styles (characteristic way of taking in and processing information) has important implications for teaching and learning (Felder & Brent, 2005, p. 57). Critics of learning style models argue they have no sound theoretical basis and that the models have not been validated (Felder & Brent, 2005, p. 57). In spite of these claims, teaching strategies that address a broad spectrum of learning styles has proven to be more effective than traditional teaching methods which focus on a narrow range of styles (Felder & Brent, 2005, p. 57).

A popular learning style model is the VARK model. The VARK learning style model suggests that there are four main learning styles: read/write, visual, aural and kinaesthetic (CAST, 2018; VARK, 2019). Another learning style theory model proposed for PLAs is Kolb's Experiential Learning Theory (Abdulwahed & Nagy, 2009). Kolb's theory, introduced over 35 years ago, is a well-accepted pedagogical model of learning. According to Kolb, learning requires that students first should grasp, depict or detect knowledge, and then a phase of construction occurs to complete the learning process. The construction is a transformation of the grasped knowledge into a mental model through experiencing this knowledge. Kolb proposed that optimal learning would pass through a cycle of Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation (Kolb, 1984). Abdulwahed and Nagy (2009, p. 285) hypothesise that poor outcomes in hands-on laboratory sessions are mainly due to weak activation of the prehension dimension of the learning cycle, before coming to the laboratory. The laboratory session turns into the procedural following of instructions instead of actively constructing meaningful knowledge from it. Abdulwahed and Nagy (2009, p. 291) conclude that "introducing the virtual laboratory in the pre-laboratory preparation session has led to considerable improvement in the conceptual understanding of the students during the hands-on laboratory session". This finding is supported by qualitative and quantitative statistical data. Munford and Honey (1992) derived from these abilities four learning styles, types of learner and their learning preference as shown in figure 2.3. This highlights the importance of providing learners with multiple mode of delivery to ensure all types of learners are accommodated.

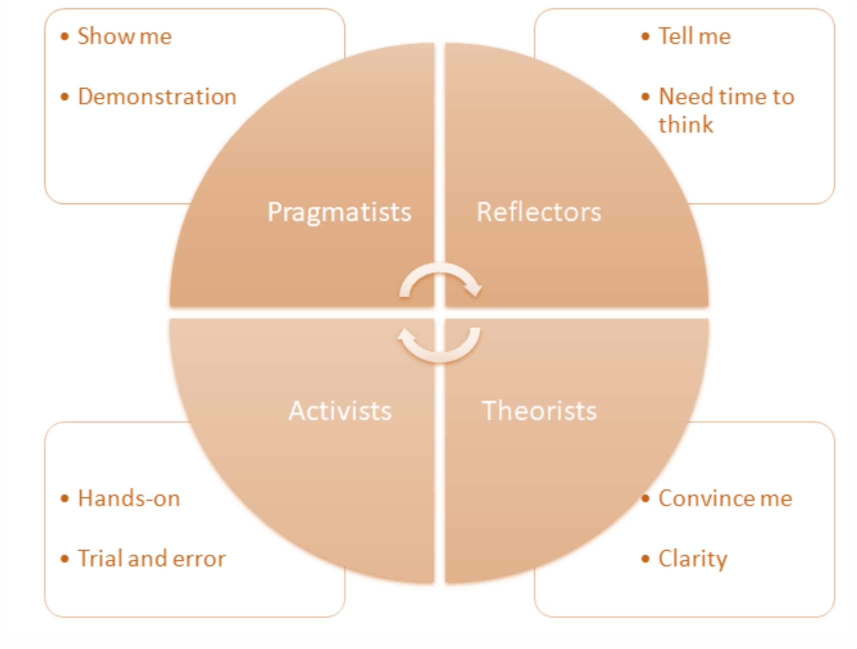

Figure 2.1 Kolb's Learning Styles Model
(adapted from Mumford & Honey, 1992)

The application of the preceding learning style models is to enable a balanced teaching approach that meets the needs of all students (Felder & Brent, 2005, p. 58). Incorporating PLAs (multimodal videos and interactive simulations) to support hands-on laboratory sessions should have a positive impact on learning, as it reduces barriers for students by not relying on anyone learning style. The next sub-section investigates Cognitive Load Theory.

2.5.3 Cognitive Load Theory

The third notable theory underpinning the pre-laboratory initiative is that of Cognitive Load Theory (CLT), which was the rationale grounding several studies on PLAs (Agustian & Seery, 2017; Jones & Edwards, 2010; Van De Heyde & Siebrits, 2019; Winberg & Berg, 2007). In the educational psychology literature, managing learning in complex environments has been extensively studied and CLT is a useful structure upon which to consider it (Agustian & Seery, 2017, p. 7). Whilst CLT is also used in cognitive psychology, the definition I am applying in this study is from the educational psychology literature. It states, CLT revolves around a "description for the amount of mental effort that is expended in any given learning scenario"; given working memory has a finite capacity (Agustian & Seery, 2017, p. 7). Heick (2017, para. 4) maintains that, because of the limits of short-term memory, "learning experiences should be designed to reduce working memory ‘load’ in order to promote schema [long-term memory] acquisition”.

Garvey, Gonzalo-Angulo and Parte (2017, p. 6) additionally argue that “users need more cognitive load to acquire, process and understand the information when the task complexity increases and users are students or novices”. Both factors – task complexity and students as users – are true in our context of the first-year electronic laboratories. The literature does point to the fact that hands-on laboratory work generates poor outcomes compared to the considerable time, cost and effort invested in the laboratory (Abdulwahed & Nagy, 2009, p. 284; Ma & Nickerson, 2006). A possible explanation is that students are at risk of “information overload” as they try to acquire new technical skills, operate new equipment and master new concepts (Jones & Edwards, 2010, p. 1).

Jayachandran et al. (2013, p. 708) list the goals of electronic laboratories, indicating the multitude of skills students need to acquire from the laboratory: apply in practice theoretical concepts, learn to use instruments, build and test electronic circuits, design and improve circuits, analyse, record and use data for verification, develop troubleshooting skills and teamwork. In traditional laboratories, this can result in cognitive overload when students are focussed on following procedures and on making their circuits work. The instructional procedures can overwhelm learners’ cognitive resources and students may fail to see connections between what they are doing and what they are meant to be learning, for example, to understand the relationship between quantities, which impacts their ability to construct knowledge (Abdulwahed, 2010, p. 40). In a robust study by Abdulwahed and Nagy (2009, p. 291), it was found that “introducing the virtual laboratory in the pre-laboratory preparation session has ....helped to reduce the cognitive load of students”.

Crucially, an effective way to reduce cognitive load and to increase deep learning during laboratory classes is with well-designed PLAs. It is evident that, in line with CLT, the more time students spend on mastering basic concepts in PLAs before having to seriously engage with them in the hands-on laboratory session, the less ‘cluttered’ their short-term memories will be (since the cognitive load will be lightened) during laboratories, and the better the students' long-term memories (schema construction) will be encouraged (Van De Heyde & Siebrits, 2019, p. 185). The next sub-section explores the recommended guideline for designing PLAs.

2.5.4 Guidelines for Designing Pre-Laboratory Activities

O'Flaherty and Phillips (2015, p. 94) identify the lack of a conceptual framework to enable a united approach to pre, in-class and post learning activities as a gap in the literature. Agustian and Seery (2017, p. 3) try to address this gap by proposing guidelines for designing PLAs. These are influenced by Van Merriënboer, Kirschner and Kester's (2003) framework for learning in complex environments and CLT. The five recommendations are:

- PLAs benefit learning in the laboratory.
- PLAs should be embedded in the overall laboratory learning process to encourage the student to see the value and engage with them.
- PLAs should focus on the whole task, drawing learners' attention to overall strategy and approaches.
- PLAs should focus on supportive information (underlying theory, general operating principles), and procedural information (specific steps, number of measurements) should be presented in the laboratory by manuals or prompts, "just in time".
- PLAs should address the affective domain. Mayer (2017), cited in Agustian and Seery (2017, p. 11), has proposed three principles to foster positive attitudes towards on-line resources: conversational style (personalisation principle), human voice (voice principle) and presenting diagrams and graphs in real time using videos or simulation tools (embodiment principle).

While the studies on PLAs are underpinned by different frameworks, for example Bloom's Taxonomy, Kolb's Experiential Learning and CLT (as discussed above); all studies indicate that there is close alignment to a broadly constructivist pedagogy. There is uniformity in relation to the focus on addressing how students grasp information and construct knowledge and the promotion of student-centred and diverse learning strategies. As observed by Agustian and Seery (2017, p. 11), most of the studies on PLAs are aligned with the CLT framework, in that case it can be argued that CLT can effectively underpin the design of the PLAs for the electronics laboratory module, among others. CLT provides “a number of instructional design rules for pre-laboratory exercises”, including multiple mode presentations that combine verbal and visual elements and having multiple representations for students to draw on (Jones & Edwards, 2010, p. 2). This idea closely aligns with the principles of Universal Design for Learning (UDL) and constructivism, both of which focus on the diversity of students' learning styles (CAST, 2018; Meyer, Rose, & Gordon, 2014). Another recommendation from Jones and Edwards (2010, p. 2) is that PLAs should be guided instructions, such as worked examples. There is strong evidence that students learn more deeply through guided instruction rather than discovery-based learning. Guided instruction leads to longer transfer of knowledge and prevents students from acquiring muddled knowledge and misconceptions (Kirschner, Sweller & Clark, 2006, cited in Jones & Edwards, 2010, p. 2).

Finally, the guidelines and recommendations for designing PLAs critiqued above, are used to underpin the design of the PLAs, for the Interface Electronics module (Abdulwahed & Nagy, 2009; Agustian & Seery, 2017; CAST, 2018; Jones & Edwards, 2010; Meyer et al., 2014; Van Merriënboer et al., 2003). The PLAs incorporate a multimedia video and an interactive on-line simulation tool, Tinkercad supporting diversity in learning styles. The videos provide guided instructions and explain the underlying theory relevant to the upcoming laboratory. The video addresses the affective domain by using the lecturers own voice and style. A link to the videos is shown in Appendix 1. The video also incorporates the simulation tool, Tinkercad to support active hands-on learning. Students are subsequently encouraged to use Tinkercad to virtually build the circuit prior to the hands-on practical laboratory. Figure 2.2 shows a screenshot of a voltage divider circuit, built in Tinkercad. All the PLAs resource materials are available on the module Moodle page, making them easily assessable for students to engage with and to understand where they fit within the overall laboratory learning process. (Details are shown in Appendix 1).

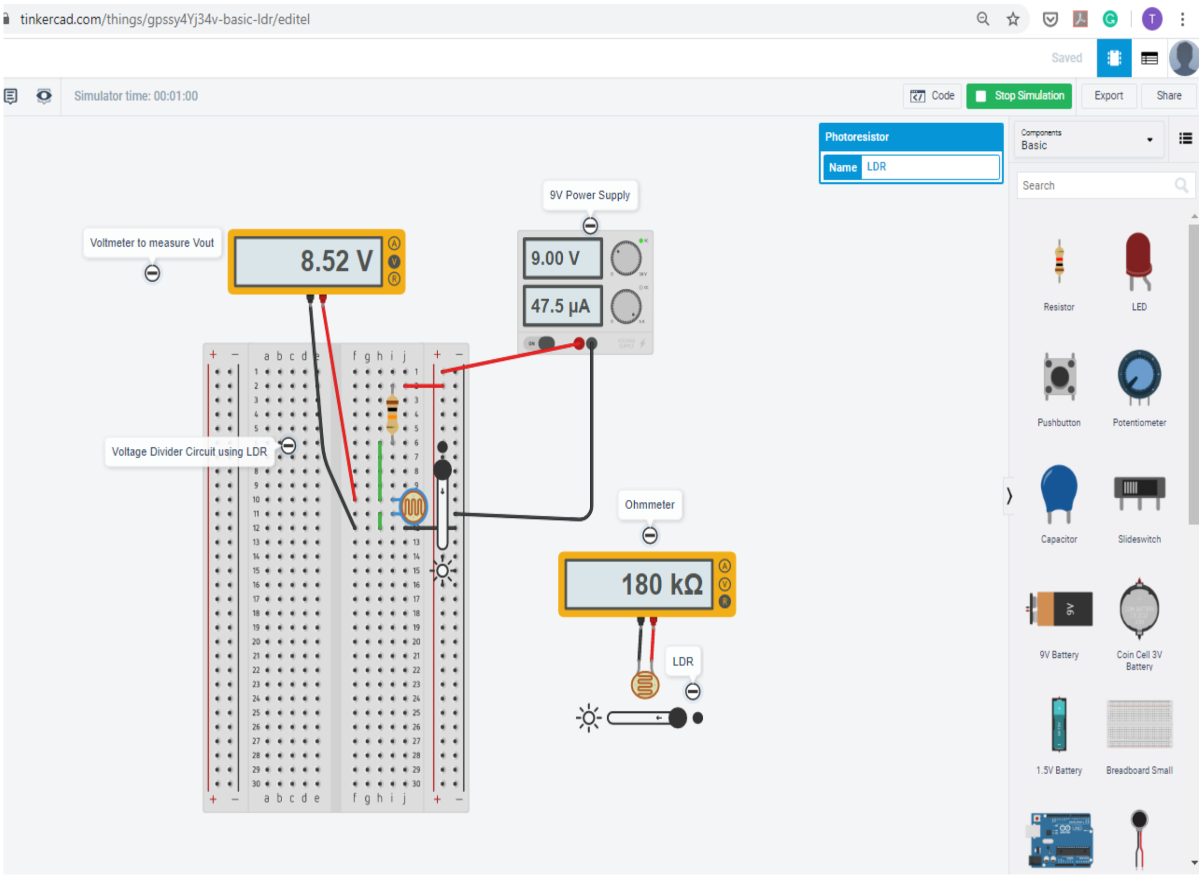

Figure 2.2 A Voltage Divider Circuit - Built in Tinkercad.

The overall objective of this study is to understand if these PLAs improve students' engagement with laboratory learning and to get student perspectives of this topic. Chapter 3 will outline the research methods to meet this objective.

2.6 Conclusions

This chapter provides an analysis of the literature and meets Objection 1, 2 and 3 set-out in section 1.2. Section 2.2 outlines the literature analysis methodology. Given the literature analysis consists of a broad search of several databases and conference proceedings, one can conclude it gives coherence to the whole study. Section 2.3 investigated the term 'student engagement', in order to establish a sound definition for the purposes of this study. The investigation concluded, as shown in Table 2.1, that a suitable framework to measure student engagement, for the purposes of this study, is based on Schindler et al.'s framework (2017, p. 5). Therefore, the themes of behavioural engagement, emotional engagement and cognitive engagement frame the data gathering design, process and tools as discussed in Chapter 3.

Section 2.4 evaluates the benefits and challenges of a flipped classroom strategy, with focus on the use of PLAs. The literature consistently indicates that PLAs are an effective teaching strategy to promote student engagement but also highlights the fact that there are some challenges: PLAs are not a “magic bullet” fix to meet the demands of the complex laboratory learning environment. Section 2.5 concludes, based on literature evidence that the learning theories compatible with PLAs include; constructivism, learning style theory and CLT. These learning theories and the recommended guidelines contribute to this study by influencing the design of the PLAs, namely the video and Tinkercad. This study evaluates if these PLAs effect students’ engagement.

Having established a reliable literature underpinning for this study, Chapter 3 progresses to a discussion on, and justification of, the research methodology and the research methods used to evaluate the impact of the PLAs on student engagement, with the practical laboratory element of the Interface Electronics module.

CHAPTER 3 : RESEARCH METHODOLOGY AND METHODS

3.1 Introduction

This chapter addresses Objective 4 of the research study (as outlined in section 1.2), namely, to design and conduct an AR study to evaluate students' engagement with, and their perceptions of engagement with, the PLAs. It provides a comprehensive account of the research methodology and the research methods used for the data gathering phase of the research study, including a justification for their use.

Section 3.2 defines the term research methodology and gives an overview of the research methodology chosen to meet the research objectives of this study. In section 3.3, selected philosophical assumptions underpinning social science research are explored - including objectivism, interpretivism, constructivism, participatory action and pragmatism - to consider how these assumptions influence the design of the research methodology. A rationale is given for the philosophical perspectives chosen to underpin the research objectives of this study, namely interpretivism, constructivism and pragmatism. Next, different research models and frameworks informed by these philosophical perspectives are investigated – mixed methods research, ethnography, grounded theory, action research and case studies - with a view to selection for this study. In section 3.4 and 3.5, a justification is offered for the chosen frameworks, namely a mixed methods AR study. Finally, the data collection methods employed to support the selected frameworks are discussed in detail in section 3.6.

3.2 Research Methodology

Research methodology is defined as the "principles that justify the research methods appropriate to a field of study" and it is "grounded in theoretical knowledge usually referred to as philosophy" (Carr, 2006, p. 422). Denzin and Lincoln (2003, p. 13) suggest that the researcher "approaches the world with a set of ideas, a framework (theory, ontology) that specifies a set of questions (epistemology) that he or she then examines in specific ways (methodology, analysis)". Figure 3.1 gives an overview of the research methodology chosen to meet the research objectives of this study and will be discussed in detail throughout this chapter.

Figure 3.1 Research Methodology (The Author)

The next section discusses and justifies the philosophies chosen to underpin this research.

3.3 Philosophical Assumptions

The philosophical assumptions of the researcher are important to understand as “these assumption shape the processes of research and the conduct of inquiry“ (Creswell & Plano Clark, 2011, p. 38). What Mack (2010) refers to as epistemology and ontology, others as paradigms (Cohen, Manion, & Morrison, 2018) or what Creswell (2009, p. 6) describes as “worldview” is a basic set of beliefs or assumptions that guide the actions to be taken in research. An analysis of the literature indicates there are many different co-existing philosophies in social science. Examples include; objectivism, interpretivism, constructivism, participatory action, and pragmatism (Cohen et al., 2018; Creswell & Creswell, 2018; Creswell & Plano Clark, 2011). The philosophies that structure and organize social science research encompass the following common elements: axiology—beliefs about the role of values and morals in research; ontology—assumptions about the nature of reality; epistemology—assumptions about how we know the world, how we gain knowledge, the relationship between the knower and the known; methodology—shared understanding of best means for gaining knowledge about the world; and rhetoric—shared understanding of the language of research (Cohen et al., 2018; Creswell, 2009; Kaushik & Walsh, 2019, p. 1). This section will give an overview of these philosophical approaches and how they align to the research objectives in this study.

Objectivism is a view that all true knowledge is scientific and can be measured by scientific methods and that social phenomenon and their meaning has an independent existence outside the researcher (Bryman, 2008, p. 29). This positive perspective is also referred to as the normative paradigm (Cohen et al., 2018, p. 19). Post-positivism is rooted in traditional forms of research and builds upon the positive approach discussed by Cohen et al. (2018). It is the scientific method of doing research, but post-positivism challenges the traditional notion of the absolute truth of knowledge (Creswell & Creswell, 2018, p. 7). According to Hampden-Turner, the perspective adopted by post-positive researchers begins with a theory and they collect data to indicate a failure to reject this theory (1970, cited in Cohen et al., 2018, p. 18). Post-positivism is often associated with quantitative research methods which focuses on precision, generalisability, reliability, and replicability (Kaushik & Walsh, 2019, p. 1). This approach was deemed unsuitable for the aims of this research on two grounds. Firstly, a scientific approach was not tenable due to the limited number of participants available to contribute to the research (n = 40). Secondly, this research requires that participants experience how a flipped classroom strategy in the form of PLAs impact on engagement and learning in a laboratory environment. The focus is on individuals' perceptions, which ruled out a scientific and objective approach.

Subjectivism is a view that social phenomenon and their meaning are continually being accomplished by researchers and that they are in constant construction and revision (Bryman, 2008). In contrast to objectivism, it emphasises the subjective elements in human experience and accepts that personal experiences are the foundation of factual knowledge. This anti-positive perspective is also referred to as the interpretive paradigm (Cohen et al., 2018, p. 19). Nonetheless, the interpretive paradigm still retains the ideals of researcher objectivity, where the researcher is a passive collector and interpreter of data (O'Brien, 2016). The constructivism worldview is often combined with the interpretive paradigm (Creswell & Creswell, 2018, p. 8). In this view, meanings are constructed by humans as they engage with the world they are interpreting (Crotty, 1998, cited in Creswell & Creswell, 2018, p. 8). Constructivism is typically associated with qualitative methods and literary and informal rhetoric in which the researcher relies as much as possible on the participants' view and develops subjective meanings of the phenomena (Kaushik & Walsh, 2019). The intent of the researcher is to look for the complexity of views and to interpret the meanings others have about the world. Rather than starting with a theory (as in post positivism), researchers develop a theory or meaning (Creswell & Creswell, 2018, p. 8) or a "thick description" of a particular case (Mertler, 2009, p. 8). This approach closely mirrors the aims of this research. As a researcher, my aim is to collect students' perceptions of a new teaching strategy, in the form of PLAs, and to interpret and understand how these students engage with the PLAs to transform my teaching practice. Considering this, the interpretive and constructivist philosophy are deemed as suitable lens to view this research.

The participatory worldview arose from the belief that the post-positive worldview did not fit marginalized individuals or deal with issues of social injustice. It advocates that research needs to be intertwined with politics and a political agenda (Creswell & Creswell, 2018, p. 9). This aligns with a critical theory model, as outlined by Cohen et al. (2018). The authors argue that the purpose of critical theory is not merely to understand situations but to change them. The theory seeks to "emancipate the disempowered, to redress inequality and to promote individual freedoms" (Cohen et al., 2018, p. 28). It is a collaborative approach in which participants are involved at each step of research. A key objective of my research study is to enact change, as, for example, the improvement of teaching practice. However, my research does not consider non-classroom variables, such as the department or the campus environment, nor deal with political or social issues explicitly. Therefore, while the emancipatory dimensions of the participatory and critical theory model were considered relevant, overall, this theory was deemed as insufficiently aligned with the research objectives of my study.

The philosophical movement of pragmatism began as a consequence of the fundamental agreement of scholars, including Dewey, Mead and Bentley, over the rejection of traditional assumptions about the nature of reality, knowledge, and inquiry

(Kaushik & Walsh, 2019). Powell (2001, p. 884) suggests that, to a pragmatist, "the mandate of science is not to find truth or reality, the existence of which are perpetually in dispute, but to facilitate human problem-solving". A major underpinning of pragmatism is that knowledge is always based on experience and beliefs and habits that are socially constructed. It draws from Dewey's concept of inquiry which links beliefs and actions through a process of inquiry (Dewey, 1933). This focus on inquiry and action orients pragmatism towards more practical-minded researchers who want to solve real-world problems (Creswell & Plano Clark, 2011). As a research philosophy, pragmatism is not committed to any one philosophy or view of reality (Creswell, 2009). It is based on the proposition that researchers should use the philosophical and/or methodological approach that works best for the research problem that is being investigated (Tashakkori and Teddlie, 1998). It opens the door to different worldviews and assumptions and multiple methods. Instead of focusing on methods, it focuses on the research problem and uses all approaches available to understand the problem. It is the philosophical underpinning of a mixed-methods approach (Creswell & Creswell, 2018, p. 10). The evaluation of a change to teaching practice, which is a central objective of this research study, exhibits strong links to the pragmatic approach to research.

In light of the above, for this research, I am adopting an interpretivist, constructivist and pragmatic approach. The rationale for an interpretative approach is informed by the research aim, which seeks to collect participants' attitudes and experiences on how PLAs impact on their engagement with laboratory learning in a HEI electronics module. This closely aligns to the aims of the constructivist researcher who looks for multiple viewpoints and aims to construe meanings others have about a situation. This emphasis on the subjective elements rules out an objective or post-positive approach to the research. Additionally, the practical based and applied nature of this research also demands a pragmatic approach. This approach accommodates the insider-researcher role required in this study and acknowledges that the researcher is not a passive collector of data. It acknowledges that the main objective is to solve a problem and gives scope to employ whatever methods best achieve this aim.

The next section discusses the research frameworks chosen to support these philosophical perspectives of interpretivism, constructivism and pragmatism.

3.4 Research Framework: Action Research Study

There are many different styles of educational research and the key to choosing the correct framework or combination of frameworks is choosing the best “fit for purpose” to address the research objectives (Cohen, Manion, & Morrison, 2007, p. 165). Research methodologies include a wide range of approaches, ranging from ethnography, grounded theory, action research and case studies (Creswell, 2009). These four frameworks were reviewed to find a suitable framework for the objectives of this research and the philosophies of interpretivism, constructivism and pragmatism.

Ethnographies involve the descriptive cultural knowledge of a group and analysis of patterns of social interaction (Cohen et al, p. 139). Cultural knowledge or social interactions was not a focus of this research, so this approach was eliminated. Grounded theory as a research method is particularly well suited for investigating social processes that have attracted little prior research attention, where the previous research is lacking in breadth and/or depth, or where a new point of view on familiar topics appears promising (Strauss & Corbin, 1997). It derives its theoretical underpinnings from pragmatism, and it’s portrayed as a problem-solving endeavour concerned with understanding action from the human perspective (Haig, 1995). Despite these being reflective of the aims of this study, it was deemed an unsuitable framework. This method produces large amounts of data which takes significant time to manage and analyse. The researcher needs to be skilful in using these data-coding methods, all of which were not possible within the time-frame of this research project (Milliken, 2010).

A case study provides a unique example of real people in real situations and enables one to understand how ideas and abstract principle fit together (Cohen et al., 2018, p. 181). This approach marries well with the constructivist philosophy that acknowledges the complexity of the real-world and that each person constructs it in a different way. A case study is different from other approaches because the focus of the study is an in-depth exploration of a specific “case” (Thomas, 2016, p. 23).

Case studies and action research (AR) are common approaches for practice-based enquiry. McNiff et al. (2003), define AR as applied research, carried out by practitioners who have themselves identified a need for change or improvement. This definition closely mirrors the aims of this research in that, I as the lecturer-researcher have identified a change - in the form of the flipped classroom PLAs – to transform teaching practice by improving student engagement with laboratory learning. This personal dimension and my dual role of researcher and lecturer require a self-reflection element to ensure rigour, as discussed in sections 3.4.1 and section 3.6.3 (Costello, Conboy, & Donnellan, 2015; McNiff et al., 2003; Mertler, 2009). However, a case study does not explicitly promote transformation of practice or reflective practice. The personal, transformative and reflective elements of this research are more closely aligned to an AR study (McNiff, 2010). Consequentially, a case study was ruled out and AR was deemed a more suitable fit. An in-depth analysis of an AR framework follows, with a discussion on how this approach supports the research objectives.

3.4.1 Action Research

AR has the twofold aim of action and research; action designed to bring about change in some community, organization or program and research to increase understanding on the part of the researcher (Costello et al., 2015, p. 4). AR originated from the work of Kurt Lewin in the 1940's. Lewin's (1946) model, amalgamating research and action to enhance understanding and generate change, highlights that the introduction of action into the scientific model "by no means implies that the research needed is in any respect less scientific or 'lower' than would be required for pure science" (Lewin, 1946, p. 35). Educational AR has its beginnings in the work of John Dewey who believed all professional educators should be involved in community problem solving, linking it to social constructivism and pragmatism (Vaccarino, Comrie, Murray, & Sligo, 2007, p. 7).

AR is a primary research methodology utilised in the development of pedagogic research in HEI's (Gibbs et al., 2017). The practitioner as researcher is a key principal of AR, as those who are responsible for action can improve that action (Mertler, 2009, p. 307). In my research, I have the dual role of lecturer and researcher and this is known as an insider-researcher. Insider-researchers blur the distinction between research and practice and therefore raise ethical issues (Gibbs et al., 2017, p. 9; P. Gibbs et al., 2017, p. 9). Some studies counteract the insider nature of AR by using research assistants to observe, perform interviews and run focus groups, but this is not practical in this study due to staff availability. Mertler (2009, p. 322) argues that since it's impossible to eliminate researcher effects, it's better that researchers have an awareness of the effects that the participants-as-practitioners-and-researchers are having on the research process and that they apply critical scrutiny to how their values, attitudes, actions, feelings etc. are feeding into the situation being studied. Critical to this is reflective practice, and there is wide agreement in the literature that reflection is essential to meet the dual mandate of AR (Costello et al., 2015, p. 2). Critical self-reflection forms one of the three data collection methods to ensure rigour as discussed later in section 3.6.3.

Dewey (1933) was among the first to identify reflection as a specialised form of thinking and this concept of reflective practice gained influence with the arrival of Donald Schön’s (1983) seminal work *The Reflective Practitioner: How Professionals Think in Action* (Finlay, 2008, p. 3). His model promotes the iterative and investigative nature of AR and is tied to Lewin’s view of AR as an on-going process of reflection and action. AR involves a four-step cyclical process; planning for your AR, acting on the plan, developing an action plan for future cycles, and reflecting on the process, as shown in Figure 3.2 (Mertler, 2019, p. 38). This progressive spiral of critical reflection is a tool to promote action and is intended to cultivate a deep understanding of a particular situation (Vaccarino et al., 2007, p. 8). This study facilitates cycle one of the process and it will make recommendations for cycle two.

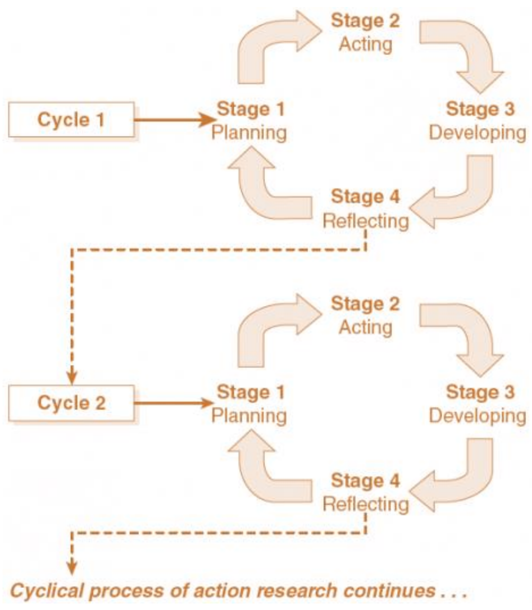

Figure 3.2 AR Cyclical Process (Mertler, 2019, p. 38).

In summary, AR was chosen to investigate the implementation of a new teaching strategy with a view to improving teaching practice. Supporting an interpretivist, constructivist and pragmatic philosophy the research allows an in-depth exploration to demonstrate that there are multiple realities and that the interpretation of each is important for understanding (Merriam, 1988). The detailed knowledge of what happens and how students engage with the new teaching strategy in the laboratory environment will lead to recommendations for future practice. In the next section, the research methods to support the AR study strategy are discussed.

3.5 Research Choice: Mixed Methods

AR studies are often qualitative in nature. Researchers adopting a qualitative perspective are more concerned to understand individuals' perceptions of the world supporting a constructivist epistemology. They seek insights rather than statistical perceptions of the world. Therefore, this necessitates the collection and analysis of narrative data (e.g. observation notes, interview transcripts) which are an integral part of the AR process (Mertler, 2009, p. 10).

In contrast, quantitative researchers collect facts and study the relationship of one set of facts to another. They collect numerical data, for example, test results, opinion ratings and attitude scales (O'Leary, 2017, p. 99). There are occasions, when qualitative researchers will draw on quantitative techniques and vice versa. This mixed methods approach is defined by Creswell and Plano Clark (2011, p. 5):

> 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.

The research choice adopted for this AR study is broadly mixed methods, but predominantly qualitative in nature. This aligns with a pragmatic approach to research and is driven by the premise that using both approaches provide a deeper understanding of the study and that one method alone will not address the research question. By using multiple sources of information and multiple measures a more holistic view of the study under investigation will emerge. Importantly for action research, as noted by Gibbs et. al., (2017, p. 9) "a more mixed methods approach could widen the impact and scrutiny of the research". If a study relies heavily on a teacher's reflection it becomes extremely dependent on personal beliefs, feelings and social values (Gibbs et al., 2017).

The quantitative method used in this study is a questionnaire with Likert scale questions. Qualitative methods include lecturer reflections, open-ended questions from student questionnaires and a focus group. This approach allows the researcher to engage in triangulation. Triangulation is the process of relating multiple sources of data in order to establish their trustworthiness or verification of the consistency of the facts while trying to account for their inherent biases (Mertler, 2009, p. 11). Laws states that "the key to triangulation is to see the same thing from different perspectives and thus to be able to confirm or challenge the findings of one method with those of another" (cited in Bell, 2014, p. 116). The next section discusses the data collection methods and tools.

3.6 Data Collection

This section details participant selection and data collection methods. It describes the data collection tools and outlines how they align to the research aim.

3.6.1 Selecting Site and Participants

The aim of this research is to improve the laboratory learning environment for the first-year students doing the Interface Electronics module, in AIT. Therefore, AIT was chosen as the research site and these students were chosen as the research participants for this mixed methods AR study. This convenience sampling is acceptable as the research strategy is an AR study, where convenience sampling is appropriate (Cohen, Manion, & Morrison, 2000, p. 103). The study only seeks to represent this group and use the findings to improve teaching practice. It does not aim to generalise to the wider population.

40 first year students were taking this module at the time of this study – 20 in Group A and 20 in Group B. Both groups have students from each program and the majority of students are doing a Level 7 program, but some are on a Level 6 and some are on a Level 8. These students were informed about the research and were given copies of the Participant Information leaflets (Appendix 2) and Consent Forms (Appendix 3). 33 students volunteered to participate (14 from Group A and 19 from Group B) in this research study and signed the consent forms. 3 students were not eligible to participate since they were under 18 years of age. 4 students decided they did not want to participate. However, as discussed in more detail in the Research Findings, Chapter 5, the average number of participants over the four-week period was 24 participants. The next sub-section discusses the data collection methods.

3.6.2 Collection Methods

Ensuring that the data collected is reliable and valid is essential to all research. Claiming that a piece of qualitative research "has validity" is, as Robson suggests, to refer to it as "being accurate, or correct, or true" (Robson 2002, cited in Costello 2011, p. 56). Given that it may be difficult (if not impossible) to verify these characteristics in qualitative data, he suggests that "(a)n alternative tack is to focus on the credibility or trustworthiness of the research". He states that one way of enhancing the credibility and trustworthiness of the data is to keep effective audit trails. All data in this study will be held for a period of twelve-months in a secure location. Mertler (2009, pp. 24-25) also focuses on the theme of rigour in action research and supports the use of triangulation, as discussed in section 3.3, as it enables the researcher to have a better understanding of what is happening and ultimately, to have greater confidence in the findings.

This section gives an overview of how the data collection methods align to the research objectives. Supported by the literature review outlined in Chapter 2, a new flipped classroom pedagogy, in the form of PLAs, was introduced to the Interface Electronics module in AIT to promote student engagement. The PLAs include a multimedia video and an interactive on-line simulation tool, Tinkercad (2019) as shown in Appendix 1. Schindler et al.'s (2017, p. 5) conceptual framework for measuring student engagement, shown in Figure 2.2, is used as the framework to inform the questions for the questionnaires, the Focus Group and to guide my reflections in determining the effect the PLAs have on engagement levels. Data is also collected on the benefits, challenges and recommendations to improve the PLAs. Table 3.1 shows how the data collection methods align to the research objective themes.

Table 3.1 Alignment of the Research Objective Themes with Research Methods.

			Methods		
Research Objectives	**Research Themes**		**Quantitative & Qualitative**	**Qualitative**	
Evaluate students' perceptions of their engagement with the PLAs	**Student Engagement**	**Indicators**	**Questionnaire**	**Focus Group**	**Reflection Journal**
	Behavioural	Participation	√	√	√
		Interaction		√	√
	Emotional	Interests and value	√	√	√
		Sense of belonging	√	√	√
	Cognitive	Motivation/ Confidence	√	√	√
		Persistence	√	√	√
		Deep processing of information	√	√	√

Having discussed the requirement for validity and rigour in data collection methods, the next sub-section discusses the tools in detail.

3.6.3 Reflective Journal Design

AR is a mode of research that places the practitioner at the core of the action and it is this personal dimension that sets AR apart from other modes of research (McNiff, 2010). A key theme in the literature is that professional reflection is a central focus of AR (McNiff, 2010; Mertler, 2019; Schön, 2017; Vaccarino et al., 2007). According to AR theory, "change does not come about as a result of spontaneous acts, but through reflection on and understanding of specific problems within their social, political, and historical contexts" (Selener, 1997, p. 105 cited in Vaccarino et al., 2007). As McNiff (2010, p. 11) warns, "some researchers focus only on the actions and procedures, and this can weaken the authenticity of the research". To ensure that reflection was a key element of this AR study, the literature was analysed to see how best to carry this out. One of the models of reflection commonly used in education is Gibbs' Reflective Cycle (Gibbs, 1988), as shown in Figure 3.3. Built from Kolb's experiential learning cycle discussed in section 2.5.2, it suggests that theory and practice enrich each other in a never-ending cycle (Finlay, 2008, p. 8).

Figure 3.3. Gibbs' Reflective Cycle (Gibbs, 1988)

Furthermore, in an AR case study carried out by Costello et al. (2015, p. 20), one of the concerns highlighted was the lack of rigour and guidance on the reflection process. To provide a structured approach to carrying out reflections they leveraged Bob Dick's work which consisted of *questions for critical reflection*. Costello et al. found that in Dick's experience of AR studies; the quality of reflection after the event is significantly helped by "careful observation during the event". In addition, reflection is not just an ad hoc process but the result of "good planning and in particular the surfacing of assumptions, before the event" (Dick, 2002 cited in Costello et al., 2015, p. 21). As a result of Dick's questions, Costello et al. designed a questionnaire to facilitate reflective practice. The practitioner found the structured questionnaire "as being very beneficial to his process of learning" in direct contrast to the reflection done is an ad hoc manner, which had a poor impact on learning (Costello et al., 2015, p. 25).

In consideration of these literature findings and leveraging off Gibbs' model and Costello et al.'s work, a Reflective Journal questionnaire, shown in Appendix 5, was designed to provide a structure to the reflection process for this AR study. In light of Schön's (2017) influential work, it is also important that professionals examine their experience and responses as they occur, reflection-in-action. Finlay, referring to Schön argues, that professionals draw on both practical experience and theory as they think on their feet and improvise and that both reflection-in and on-action allows them to revise, modify and refine their expertise (Finlay, 2008, p. 4). Therefore, observations and actions made by the researcher during the laboratory session are vital to capture in the reflective journals. The reflective journals were written-in directly after the laboratory class for Group B over the four-week research period. An audio recording, following the journal structure, was recorded directly after the laboratory classes for Group A and transcribed later as shown in Appendix 12. Of importance, is this personal reflection on the part of the researcher will add to the validity of the research findings (McNiff, 2010, p. 11). Next, the questionnaire design is explored.

3.6.4 Questionnaire Design

A survey is a form of planned data collection for the purpose of description or prediction as a guide to action (Oppenheim, 1966). To gather data, surveys use questionnaires, attitude scale, interviews and various other methods. For this research, a questionnaire was designed to document the experience of student-participants using the PLAs and to provide an insight into how effective the PLAs are at promoting student engagement. A questionnaire is not just a list of questions but a scientific instrument for measurement and collection of particular data and therefore, can only be judged as effective if it meets its stated goal (Cohen et al., 2018). As shown in Table 3.1, the student questionnaire was devised, in line with the literature findings outlined in Chapter 2, to examine student insights under four main themes: 1) behavioural engagement 2) emotional engagement 3) cognitive engagement and 4) areas for development to teaching practices.

The questionnaire used a Likert scale response to statements to allow analysis of the participants' attitudes towards the PLAs more quantitatively (Cohen et al., 2018, p. 253). The participants have the option to give a degree of opinion on whether they strongly agree or strongly disagree with a statement as opposed to just giving a yes or no answer, as shown in Figure 3.4. The questionnaire also asked the participants to "explain your choice", also shown in Figure 3.4.

2. I enjoyed doing the pre-laboratory activities.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____

Figure 3.4 A Sample Statement from the Questionnaire

Additionally, it posed some open-ended questions giving students the scope to give a detailed response to questions. This allowed the collection of both quantitative and qualitative data supporting the mixed methods strategy discussed in section 3.5 and the pragmatic approach discussed in section 3.3. For example, participants are asked if they have any suggestions to improve the PLAs. The complete questionnaire is shown in Appendix 6.

The questionnaire was a paper-based questionnaire. It was administered during class time over a four-week period during weeks 6, 7, 9 and 10 of semester 1. Students who are absent on the day did not get to complete the questionnaire. The students were given five minutes at the start of the laboratory session to answers questions on the PLAs. After they completed the laboratory practical, at the end of class, they were asked to spend a further five minutes doing the post-laboratory questionnaire. Students filled in the questionnaires anonymously. It was felt this was an important aspect of the questionnaire design given the dual role of the researcher as lecturer and researcher. Students may be reluctant to voice their criticisms and misgivings to one who has power over them and can influence their grades. If anonymity is assured, students may be more willing to be honest and put their concerns in writing (Moon, p.119). Nonetheless, the possibilities for bias responses are still possible given students know I will be reading their responses and they may give me the answers they think I want to receive as opposed to being totally honest. These challenges can be somewhat balanced, by validating the findings using triangulation with the other data collection methods. Next, the pilot study of the above data collection tools is discussed.

3.6.5 Pilot Study

A pilot study was carried out on the questionnaire design and the reflective journal design during week 6. According to Creswell (2018), it is normal practice in qualitative research to conduct a pilot study and it is an important stage to establish if the research instruments are valid. The pilot stage of the questionnaire allowed one to test the usefulness of the instrument and to establish how long it took students to complete. Students in Group A (n=13) were given the questionnaire during week 6. The pilot study indicated that the five-minutes pre- and post-laboratory were enough to complete the questionnaire, meeting the planned ten-minutes allocated to this tool.

The students (n=13) were asked for their feedback on the clarity of the instructions and if the questions were meaningful. There was consensus among the students that the instructions were clear, and they were happy with the questions. However, an initial review of the questionnaires collected, found that all students engaged with the quantitative questions but some students (n=5) left the qualitative open-ended questions blank. Based on this, I changed my strategy when getting students to complete the questionnaire. I guided students through the questions and asked them to explain their choices. This was easily implemented for the pre-laboratory questionnaire as all students were starting together. However, for the post-laboratory questionnaire, this intervention was more difficult. The students finished the laboratory at different times, and it was not possible to co-ordinate students to do the questionnaire in unison. This difficulty remained an on-going challenge during this study and may have impacted the completeness of the post-laboratory qualitative data.

The pilot study also highlighted a drawback to the anonymous surveys; I did not have visibility on who returned the surveys. There was no guarantee that those who did not consent took a questionnaire and filled it in. On balance, I had to trust that students were well informed and only those who agreed to participate did. In fact, the average number of students' who returned questionnaires (n=24) was always less than the number that agreed to participate (n=33). This occurred despite encouragement and reminders to participants to complete and submit the questionnaire prior to leaving the laboratory.

Week 6 was used as a pilot study for the reflective journals. One finding from the pilot study was I did not have time to complete the reflective journal after the Group A laboratory session as it occurred at the end of the day and I needed to start my commute home. Based on this, I decided that recording my reflections during my commute was the most effective way of capturing my feelings and thoughts as this enabled me to reflect on my actions in a timely manner. This aligns with Philips and Carr's assertion that an important point for reflective practice, is that data is captured as close to the event as possible (Phillips & Carr, 2010, p. 189). Next, a focus group is discussed.

3.6.6 Focus Group Design

A focus group is a form of group interview; however, the focus is on the interaction within the group to discuss a topic supplied by the researcher (Cohen et al., 2018, p. 288). It is from the interaction of the group that the data emerges, hence the dynamics of the group are important (Denscombe, 2012, p. 189). This allows the views of the participants to emerge and the participants' agenda can dominate over the researchers. The aim of the focus group is to gain as accurate a picture as possible of students' experiences of using the PLA and how these impact on their engagement. This collection method aligns with the constructivist philosophy discussed in section 3.3, where individuals' experiences contribute to knowledge generation. The focus group data is important to triangulate the findings with those from the other data collection tools, namely the questionnaires and the reflective journals for data reliability and validity (Mertler, 2009). The focus group built-on the questionnaire, addressing the same themes; 1) behavioural engagement 2) emotional engagement 3) cognitive engagement and 4) areas for development. The data is collected via unstructured and open-ended questions (see Appendix 8). This gives the participants scope to provide a deeper understanding of their experiences using the PLAs and their opinions of the PLAs.

Students were asked to volunteer to participate in the Focus Group. These participants were asked to read and sign the consent forms (Appendix 4). The target was 4 to 6 participants to represent the group (n=40). Morgan suggests that between 4 and 12 people is a good number to ensure the group is not hard to manage or the group is not too small to affect the intra-group dynamic (1988, cited in Cohen et al. p. 288). 7 students (4 students from Group A and 3 from Group B) volunteered to participate in a focus group and these were convenience sampled and sent an email invitation to the focus group (Appendix 7). This over-recruiting of participants allowed for participants not "turning up" and Cohen et al. (2018) suggest a 20% over-recruiting rate. The focus group was scheduled outside of class time at a time both student groups were free. 5 participants attended the focus group - 3 from Group A and 2 from Group B.

One concern over focus groups is that the presence of the researcher may influence and bias the participants' response to what they think I would like to hear (Creswell & Creswell, 2018). In addition, participants need to have something to say and feel comfortable enough to say it (Cohen et al., 2018, p. 288). To address these issues, time was spent articulating to the participants the goal of the focus group, their expected role (give their opinions both positive and negative, no right or wrong answers) and the group rules (one voice at a time and everyone must participate). Please see Appendix 8 for full details. The group discussion then proceeded, and an audio recording and written notes were taken during the meeting. Having discussed the three data collection tools – questionnaires, reflective journals and a focus group

– to be used in this study, the next section debates the ethical considerations for this study.

3.7 Ethical Considerations

There are five main ethical principles in educational research according to Hammersley and Traianou (2012, pp. 2-3); minimising harm, respecting autonomy, protecting privacy, offering reciprocity and treating people equitably. These five principles have been considered as part of this research design and a key element was preparing the Participant Information leaflet (Appendix 2) and Informed Consent Forms (Appendix 3&4). These were approved by the MA in Teaching and Learning Research Ethics Committee at GMIT. Students' informed consent was requested as part of the data gathering process thereby respecting their autonomy. Students volunteered to part-take in this research and could withdraw within one month of participation without explanation and fear of penalty.

In an AR project, students are participants in the research on a course where the students' work is assessed and contributes to their final grade for the course. This poses a challenge that the researcher needs to be mindful of, as students may feel obliged to participate or to respond in a particular way (Gibbs et al., 2017). This is significant considering Hammersley and Traianou (2012) final two points on offering reciprocity and the equitable treatment of people. It requires that all individuals I interact with during the research study should be treated equally, and that no one benefits unduly by partaking or is discriminated against if they choose not to participate. The research design does not pose any harm to students and it does not bias any group of students in favour of another. Some of the students in the group were under 18 and therefore were not eligible to partake.

Consideration was given to the use of class-time to carry-out this research. Participants filled in the 10-minute questionnaires during class-time. From an ethical perspective, this was felt to be an appropriate length since they consumed a small portion of the students' two-hour laboratory practical. In addition, I believe the limited class-time given to the research did not exclude or impact unduly on the students who were ineligible to participate due to age or those that chose not to participate. No student expressed that their learning was compromised or that they felt discomfort.

In addition, participants' information is kept confidential and no identifying factors relating to participants, is in evidence in any reports thereby protecting their privacy. All electronic material is stored in a secure encrypted folder and paper-based questionnaires are stored in a locked drawer. The data will be stored for a 12-month period (Mertler, 2009). As demonstrated, due consideration was given to the main ethical principles as outlined by Hammersley & Traianou (2012).

3.8 Conclusion

The objectives of this chapter were to describe the research methodology and methods employed in this study (See section 1.2 for the objectives). Figure 3.1 gives an overview of the research methodology chosen to meet the objectives of this research study. It was concluded that the research philosophies most suitable to underpin this research are interpretivism, constructivism and pragmatism. Interpretivism and constructivism closely aligns to the research objective which seeks to collect participants' attitudes and experiences on how PLAs impact on their engagement with laboratory learning and the practical and applied based nature of this research demands a pragmatic approach.

Section 3.4 analyses the research frameworks to find the most appropriate approach to support the research objectives. It concludes that a mixed methods AR study is the most suitable framework. AR was chosen to investigate the implementation of a new teaching strategy with a view to improving teaching practice. A mixed methods research choice supports the pragmatic approach to research and enables multiple sources of evidence for an in-depth and broad investigation. These include a questionnaire and a focus group involving participants taking the Interface Electronics module as part of their first year BEng in Computer Engineering course at AIT. Given AR is a key research method; reflective practice using reflective journals was also an important data collection tool. The chosen data collection tools are broadly mixed methods, but predominantly qualitative in nature. Section 3.7 concludes that due attention has been given to the ethical considerations of this research study.

In summary, this chapter demonstrates the effectiveness of the chosen research methodology and methods to meet the objectives of this research. Chapter 4 discusses the research findings obtained as a result of the data analysis and research methods.

CHAPTER 4 : FINDINGS FROM THE ACTION RESEARCH STUDY

4.1 Introduction

This chapter presents the findings from the primary research phase of this research study, as discussed in Chapter 3. An analysis of these findings follows in Chapter 5. The findings endeavour to address the research aim, which is to evaluate the effects of flipped classroom PLAs on students' engagement with laboratory learning. More specifically, they will address Objective 4, namely, to conduct an action research study to evaluate students' engagement with and their perceptions of their engagement with, PLAs. The findings for this study are presented thematically according to the three main themes used to measure student engagement, as discussed in Chapter 2 and detailed in Table 3.1. Section 4.2.1 outlines how the research findings are presented and structured. Section 4.2.1 presents the findings for Behavioural Engagement, section 4.2.2 presents the findings for Emotional Engagement, and finally, section 4.2.3 presents the findings for Cognitive Engagement.

4.2 Structuring the Research Findings

For each of the three themes outlined above, the findings are sub-divided into 1) quantitative findings from the questionnaires and 2) qualitative findings from the questionnaires and the Focus Group. The data collected in my reflective journals gathered over the four-week research provide insights and observations and therefore is predominantly used to support the analysis and discussion of the findings in Chapter 5. Furthermore, any factual findings from my reflection journals is occasionally woven into the qualitative findings in this chapter.

The quantitative findings were extracted from the paper-copy questionnaires submitted by the participants over the four-week research period. This data was manually input into an excel spreadsheet and analysed. A snapshot of the excel data is shown in Appendix 10. The findings from the quantitative data are presented in chart format for the four-week research period for the four laboratories (Lab 4, Lab 5, Lab 6 and Lab 7). The data over the four-weeks was also amalgamated and a summary of this data is presented in chart format. As an example, Figure 4.8 shows the number of participants' responses to Statement 2 "I enjoyed doing the PLAs", over the four weeks of laboratories. Figure 4.7 shows a summary, represented by a percentage, of participants' responses to all the emotional-themed statements, including the statement "I enjoyed doing the PLAs". Given the small sample sizes, the percentage data is not statistically robust. Despite this concern, in the context of summarising the findings over the four weeks of research and providing a proportional comparison between the findings, using percentage data was considered acceptable.

In most cases, the findings for Group A and Group B are merged together. The main reason for this is to simplify the presentation of results. This is a justifiable approach as the sample sizes are small for both groups and the objective of this research is not a comparison but rather to get an overall understanding of students' engagement with the PLAs and to understand their perceptions of the PLAs. Also, there is no significant difference between the students in Group A and Group B.

The qualitative findings from the questionnaires and the Focus Group were transcribed. A double hermeneutic methodological approach was applied to these comments (Cohen et al., 2018). I used my interpretation of the participants' comments and insights to colour-code them according to the main indicators for each of the three themes of engagement – Behavioural, Emotional and Cognitive - as outlined in Table 3.1 in section 3.6. For example, as shown in Table 3.1, an indicator of emotional engagement is students demonstrating a value and interest towards learning. I interpreted participants' comments – "it was informational", "I found them interesting" – and categorised them according to the indicator, in this example, "value". All comments falling under this category were given a colour-code and then counted. A snapshot is shown in Appendix 11. This frequency analysis is presented in chart format in the Qualitative Data Findings sub-sections – see Figure 4.11 and Figure 4.19. The data from the focus group discussion, supporting the three themes and the student focused indicators of each theme as shown in Table 3.1, is also presented. Next, the findings for the theme of behavioural engagement is discussed.

4.3 Findings for the Theme of Behavioural Engagement

This section considers how the PLAs impact on students' behavioural engagement with laboratory learning. As outlined in section 2.3.2, indicators of positive behavioural engagement include attendance and taking an active part in classes, paying attention, asking questions and making efforts and interactions with peers or staff. Firstly, quantitative data from attendance records and data on the number of students who participated in this research is presented in section 4.3.1. Next, the responses to Question 1 and Statement 8 from the questionnaire, as shown in Appendix 6, is presented. This data collects inputs on participants' use of the PLAs and their perceptions of their engagement levels in the laboratory. Finally, the findings based on the qualitative data from the questionnaires and the focus group is presented in section 4.3.2.

4.3.1 Quantitative Data Findings

A key indicator of behavioural engagement is student participation in their learning and a measure of this is attendance (Coates, 2010; Kahu, 2013; Kuh, 2009; Schindler et al., 2017; Trowler, 2010) . Attendance at the laboratory practical over the four-week period for this research is presented in Figure 4.1 for Group A and Figure 4.2 for Group B. As can be seen in Figure 4.1, Group A's attendance was good and consistent over the four weeks. 18 students were present every week out of 20.

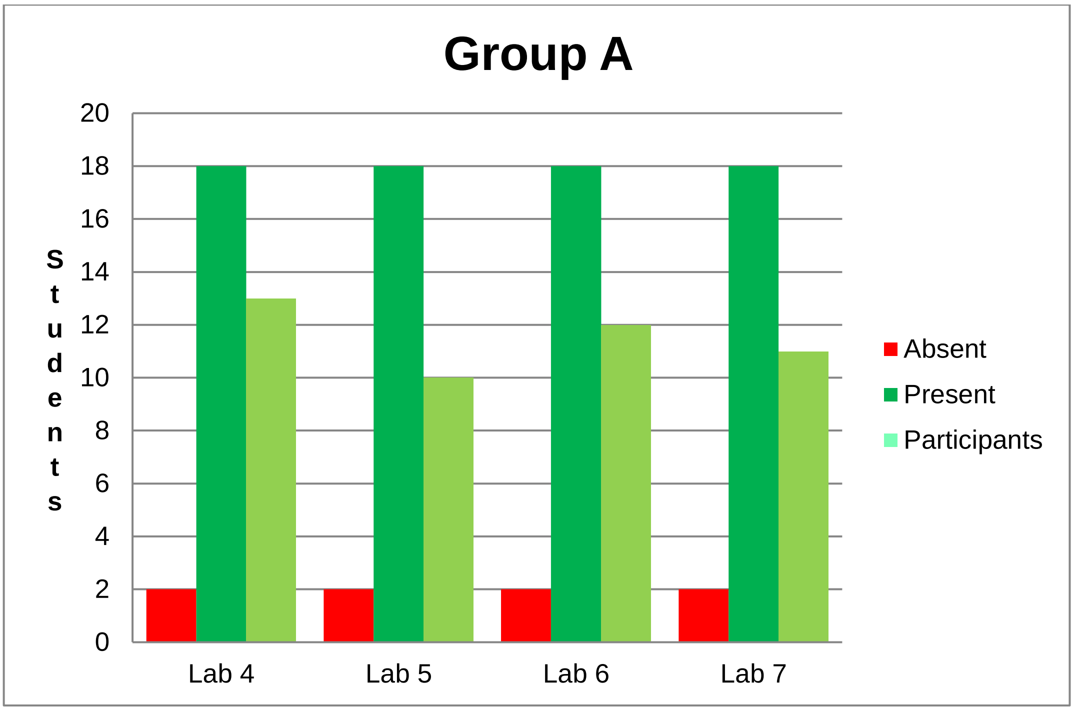

Figure 4.1 Group A: Attendance in Laboratories and Participation in Research

Student attendance in the laboratory for Group B was poorer than Group A with an average attendance of 15 out of 20 over the four weeks. The Group B attendance deteriorated significantly in the fourth week of this research. As shown in Figure 4.2, in Lab 7 there was very poor attendance with 9 students out of 20 absent.

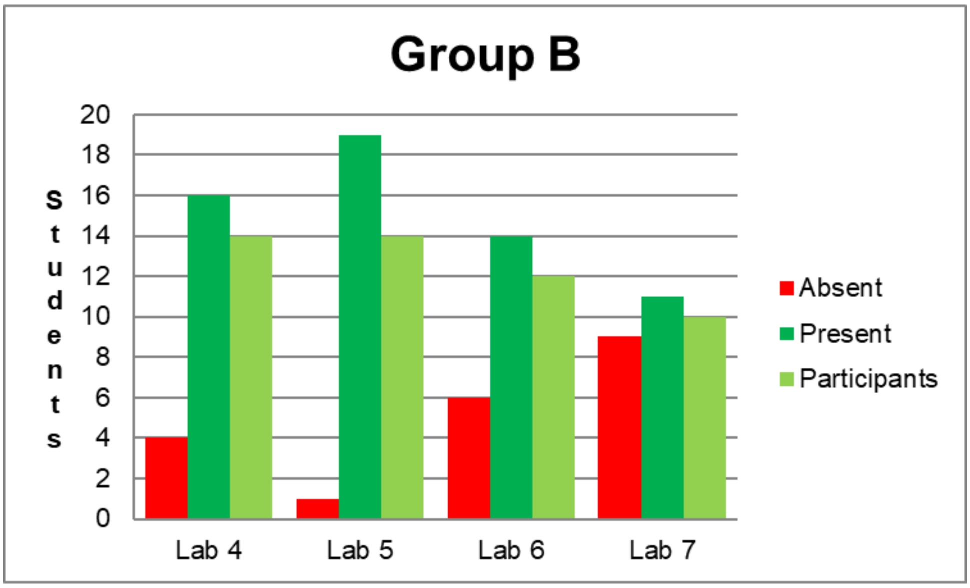

Figure 4.2 Group B: Attendance in Laboratories and Participation in Research

The charts shown in Figure 4.1 and Figure 4.2 also show the number of students from each group that participated in this research study, by completing the questionnaires over the four-weeks of data gathering. Figure 4.1 shows of the 14 students that agreed to participate from Group A, an average of 11.5 did over the four weeks (Lab 4, n=13; Lab 5, n= 10; Lab 6, n= 12; Lab 7, n=11). Figure 4.2 shows of the 19 students that agreed to participate from Group B, an average of 12.5 did over the four weeks (Lab 4, n=14; Lab 5, n= 14; Lab 6, n= 12; Lab 7, n=10). In summary, there was an average of 24 participants every week which is 75% of the students present on a weekly basis (n=35). The subsequent findings are based on the data collected from these participants. In addition, throughout the four-week process, approximately 10% of participants left a blank response to a statement and this is reflected in the numbers presented.

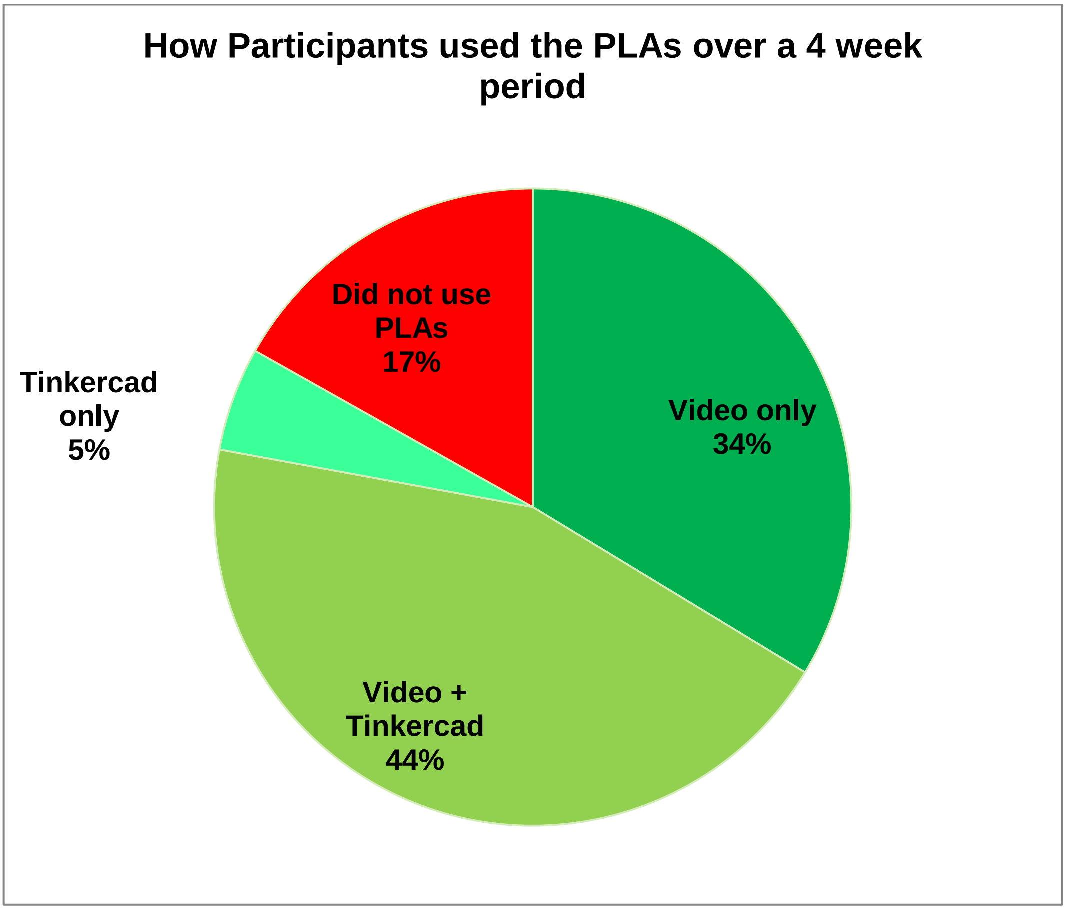

Figure 4.3 How the Participants used the PLAs over the Four Weeks

Participants' quantitative responses to Question 1 in the questionnaires, "How did you prepare for this laboratory? Tick as appropriate", indicates there was strong engagement with the PLAs during the four-week research period. As shown in Figure 4.3, 83% of participants used the PLAs and 17% did not use them. The data indicates most students watched the video (78%). Of this 78%, 44% watched the video and simulated their circuit using Tinkercad. 34% only watched the video and 5% only used Tinkercad. On three occasions participants stated they did "other" activities which they noted as "looked at lecture notes, did on-line quiz and practised equations". The remaining 17% of participants did not use any of the PLA resources. The primary reason given for this by participants when asked in the questionnaire was, they "forgot". Other reasons were due to illness or technical issues with a laptop.

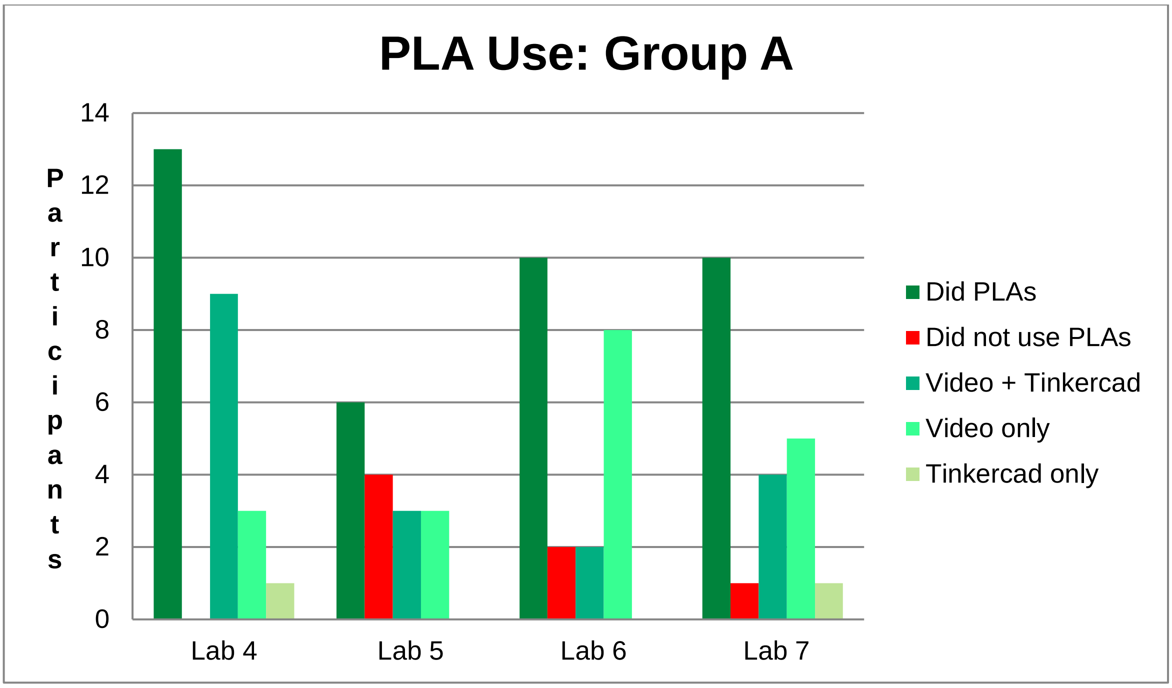

Figure 4.4 PLA Use: Group A

Figure 4.4 shows how Group A used the PLAs over the four weeks. The data shows a peak in usage for Lab 4, a drop-in usage for Lab 5 and an increase and consistent use of the PLAs for Lab 6 and Lab 7. Group A data suggests a trend that participants' use of Tinkercad decreased after Lab 4 and more participants only watched the video in Lab 6 and Lab 7 than watched video and did Tinkercad.

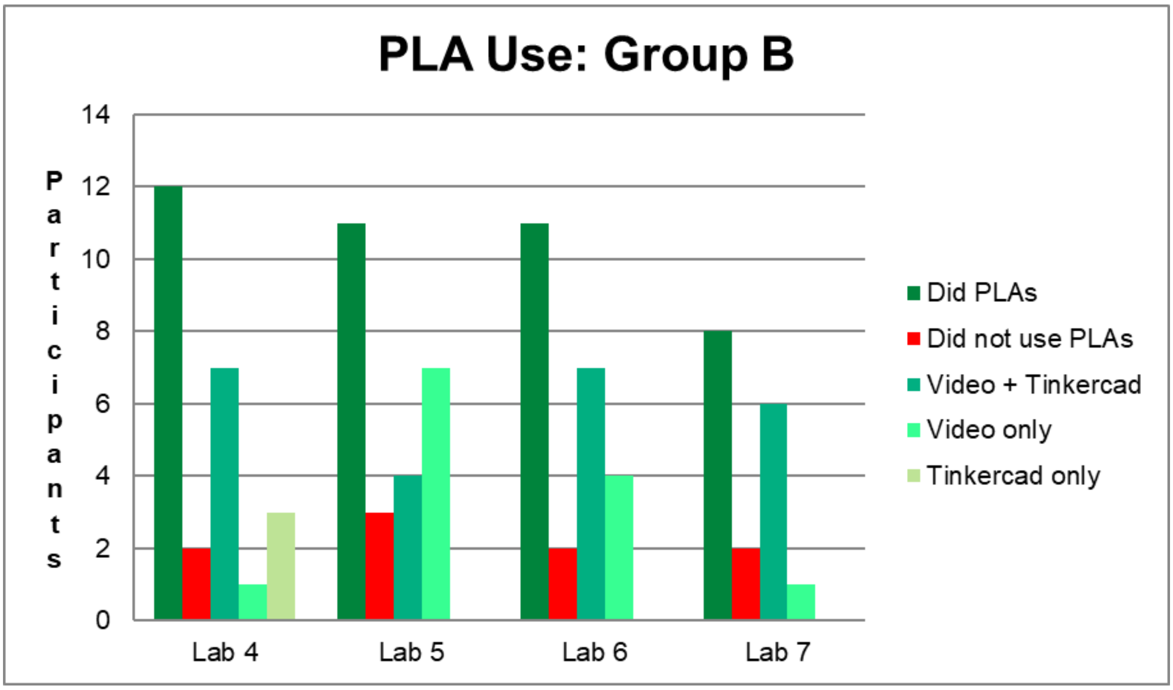

Figure 4.5 PLA Use: Group B

Figure 4.5 shows how Group B used the PLAs over the same period. The data shows that there was consistent use of the PLAs over the four weeks. Usage for Lab 7 was lower for Group B (n=8), but as was shown earlier in Figure 4.2, this data is influenced by the lower number of students attending Lab 7 (n=11). Tinkercad use was more consistent in Group B over the four-weeks and the data did not show the trend of more participants only watching the videos.

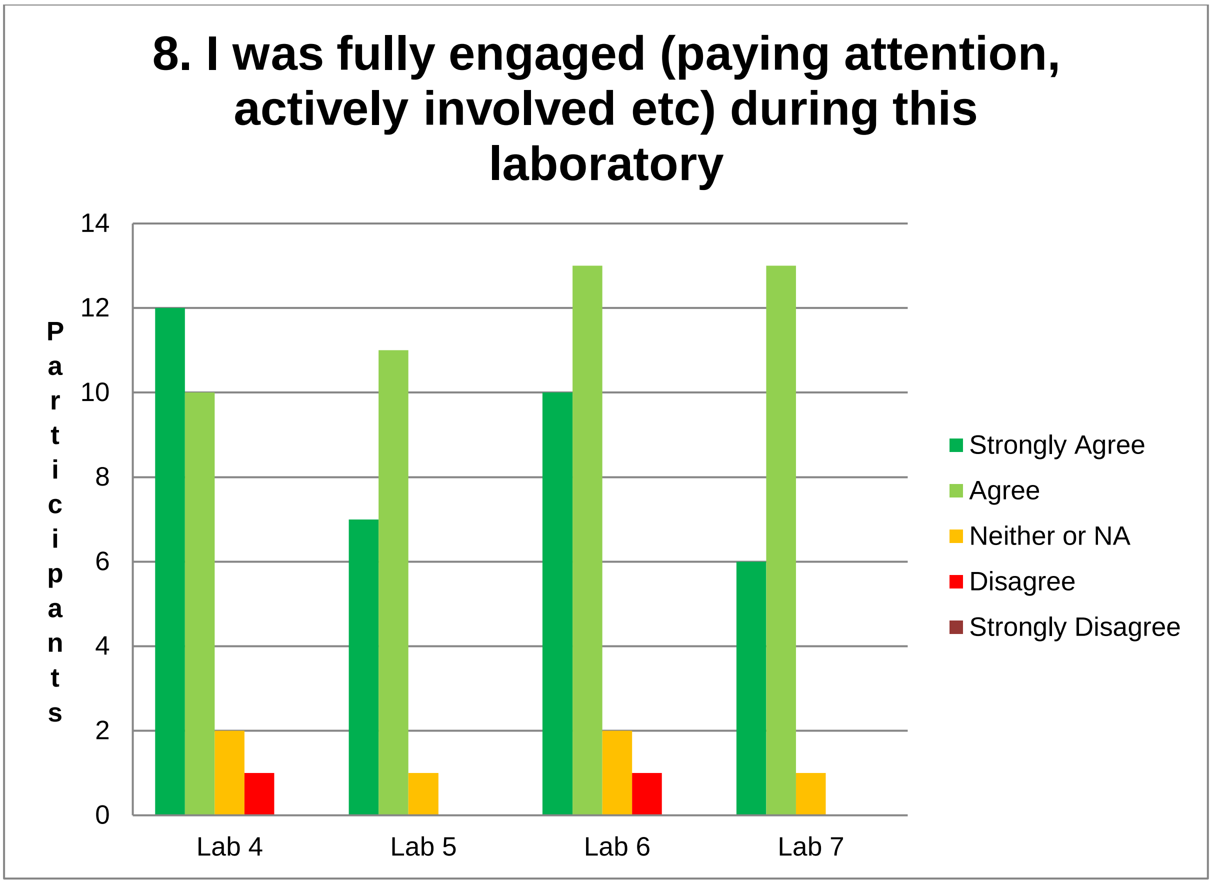

Figure 4.6 Responses to Statement 8 over the Four Weeks of Laboratories

Participants' responses to Statement 8 "I was fully engaged (paying attention, actively involved etc) during this laboratory", checking students own perceptions of their engagement during the laboratory, is shown in Figure 4.6. It indicates 36% of participants Strongly Agree and 48% of participants Agree with the statement. 6% Neither Agree nor Disagree with this statement, 2% Disagree and no participants Strongly Disagree. This trend remains consistent over the four weeks. The next section presents the qualitative data findings for behavioural engagement.

4.3.2 Qualitative Data Findings

In the area of student attendance, my reflective journals note the poorer attendance in Group B as a concern. In my journal for Lab 7, Group B I note;

> The attendance this week was very poor and concerning, especially given this week was the students' last lab before their skills lab exam. Only eleven students were present, and nine students were absent.

The journal entries support the quantitative finding that students were engaged in the laboratory and journal entries for Lab 4 Group A note;

> Good engagement from the students. Good contributions when I posed questions or asked for formulas to solve problems. Good work ethic, everyone getting stuck-in to the task. A lot of groups (n=5) were able to complete the task with little or no help, a few with a little guidance (n=3) and 2 groups needed a lot of help, but they got there in the end. Students who found it hard kept trying and were engaged. I felt most students were interested and making efforts in this lab.

They also draw attention to the fact that the quantitative findings are only representative of the participants in the research and not all students in the group. My reflection on some laboratories indicate “I felt about half the students were well prepared and had used the PLAs”. This contrasts with the data that suggests an 80% engagement with the PLAs by participants. This is analysed in more detail in section 5.2.2.

The data from the Focus Group correlates with the quantitative data on how the participants used the PLAs. Participants A, B and E explained how they watched the video first and used this to help them to build the circuit themselves in Tinkercad, as described by Participant B;

> I would watch the video in full and then I’d open up Tinkercad and start to put the circuit together. If I needed anything else to help my understanding I would re-watch parts of the video to make sure everything was going alright and just check measurements.

Participants indicated they spent ten-minutes watching the video and ten-minutes building the circuit on Tinkercad. Participants in the focus group felt this twenty-minute preparation time was acceptable. The two other participants, C and D, indicated that they watched the video every week, but they did not always use Tinkercad. Participant C states “I watched all the videos and did Tinkercad for the first couple. After, I didn’t find it necessary to do the Tinkercad, so I just watched the videos” and Participant D explains “on easier weeks” he only watched the video and he used Tinkercad on “harder weeks to understand a bit better”.

The theme of peer-to-peer interactions, as an indicator of behavioural engagement, was also discussed in the focus group discussion. Nobody used the on-line sharing feature on Tinkercad to share their circuits. A common point made by the group was that they were more likely to give assistance to their peers in the laboratory, since having done the PLAs they were more confident in their own knowledge. As described by Participant B, "...if I had my circuit built and measured and someone else was struggling, because I understood, I could turn around and help them." And Participant C notes, this collaboration in the laboratory is beneficial since "people learn better from their peers, so it works well". The reflective journals also note "good team-work" and "good collaboration". Next, the findings for the theme of emotional engagement are presented.

4.4 Findings for the Theme of Emotional Engagement

This section looks at the findings for participants' emotional engagement with the PLAs and laboratory learning. As outlined in section 2.3.2, indicators of positive emotional engagement include enjoyment of learning, interest in learning and valuing learning. Firstly, the quantitative findings from the questionnaire on participant's Likert responses to the emotional engagement statements (2, 3 and 6) are presented in section 4.4.1. These statements collect data on participants' perception of their enjoyment of the PLAs (Statement 2: "I enjoyed doing the PLAs"); the value of the PLAs for their learning (Statement 3: "I can see the value in doing the PLAs for my learning") and how the PLAs prepared them for the laboratory (Statement 6, "I feel well prepared for this laboratory because I did the PLAs"). Afterwards, the findings based on the qualitative data from the questionnaires and the focus group are presented in section 4.4.2.

4.4.1 Quantitative Data Findings

Figure 4.7 gives a summary overview of the participants' quantitative responses to Statements 2, 3 and 6 from the questionnaires on a Likert scale of Strongly Agree to Strongly Disagree. It amalgamates the data over the four weeks of laboratories and the data is presented as a percentage.

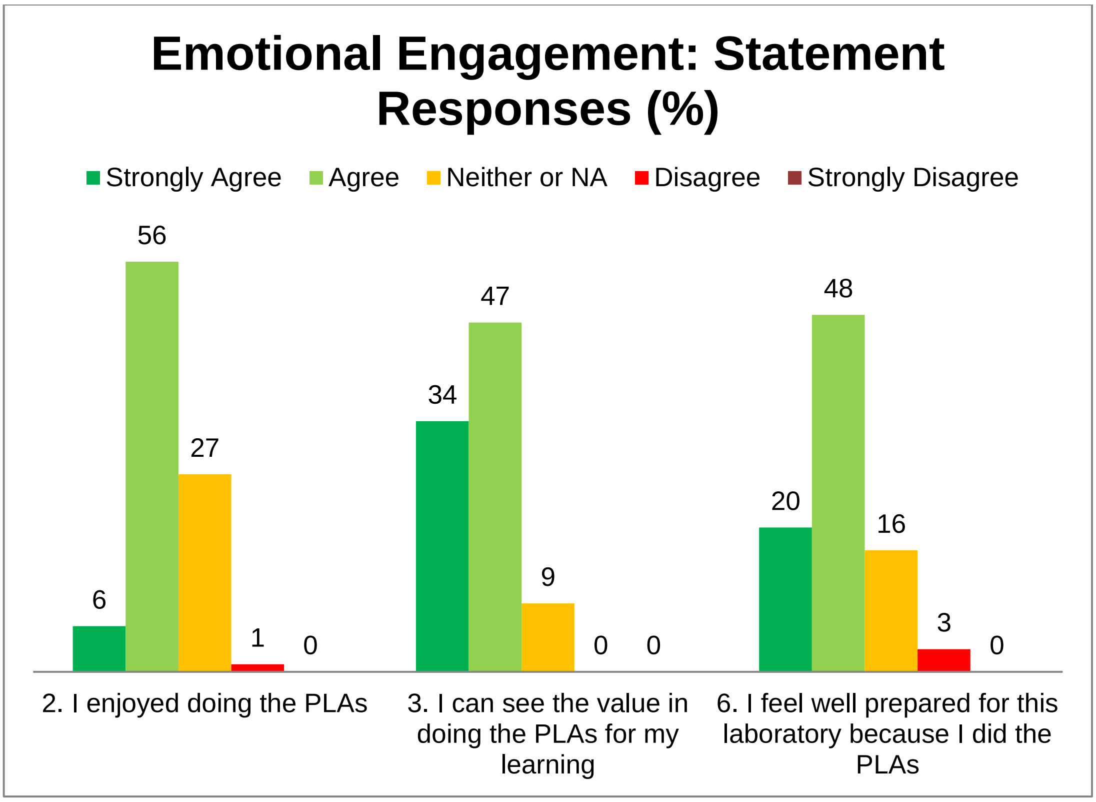

Figure 4.7 Responses to Statements on Emotional Engagement

Participants' responses to Statement 2, "I enjoyed doing the PLAs", as shown in Figure 4.7 indicate 6% of participants Strongly Agree and 56% of participants Agree with this statement. 27% of students Neither Agreed or Disagreed with this statement and 1% Disagree with the statement. No participants Strongly Disagreed.

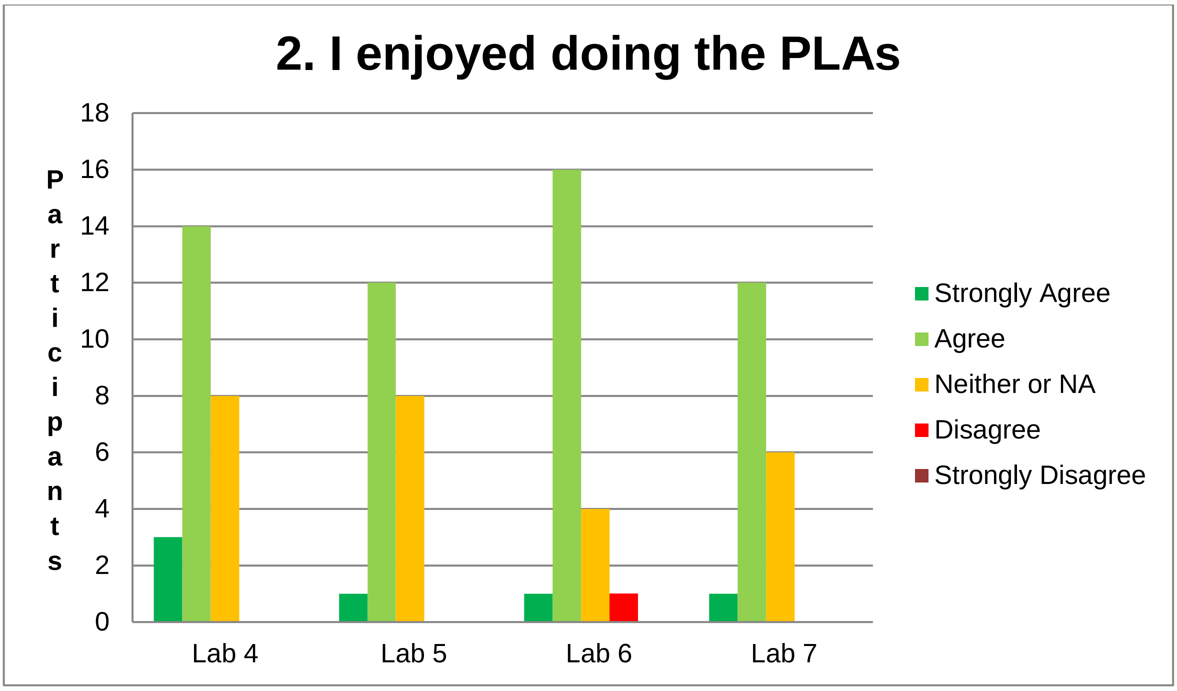

Figure 4.8 Responses to Statement 2 over the Four Weeks of Laboratories

Figure 4.8 shows the actual number of participants' responses to Statement 2 over the duration of this research for the four laboratories. As can be seen from the data, the trend that approximately 60% of students agree or strongly agree that they enjoyed doing the PLAs and 30% neither agree nor disagree remains consistent over the four weeks.

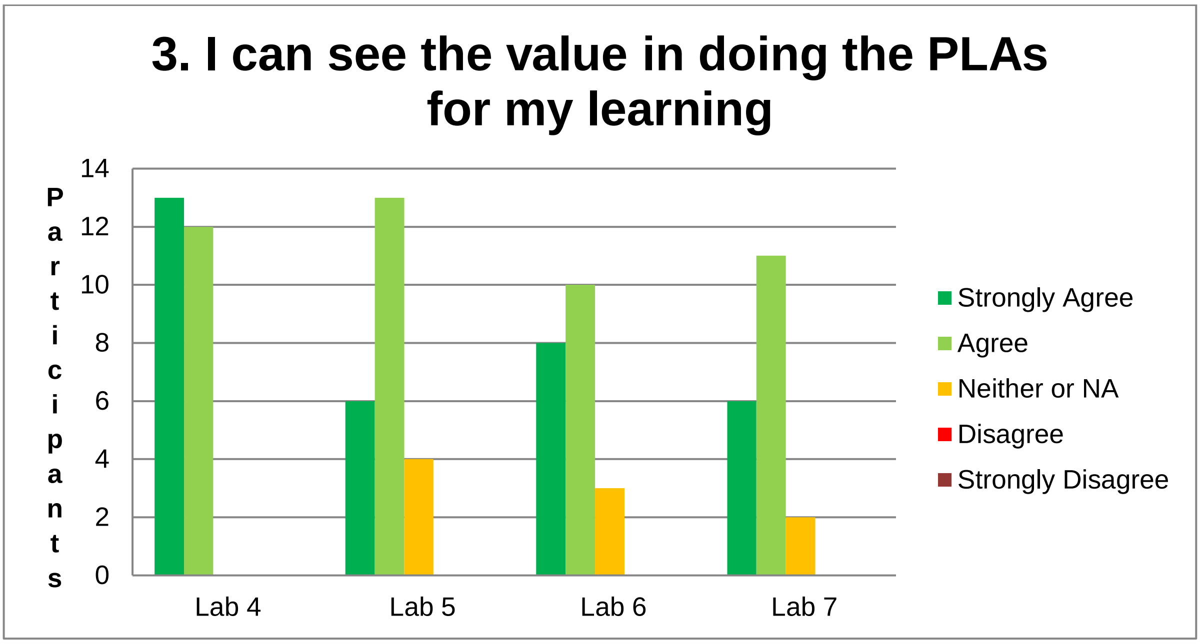

Figure 4.9 Responses to Statement 3 over the Four Weeks of Laboratories

Participants' responses to Statement 3, "I can see the value in doing the PLAs for my learning", as shown in Figure 4.7 indicate 34% of participants Strongly Agree and 47% of participants Agree with this statement. 9% of students Neither Agreed or Disagreed with this statement and no participants Disagree or Strongly Disagree with the statement. Figure 4.9 shows the actual number of participants' responses to Statement 3 over the duration of this research for the four laboratories. This shows that for first week of introducing the PLAs, Lab 4, all participants either Strongly Agree or Agree that they can see value in doing the PLAs for their learning. The number of participants who Strongly Agree drops after the first week, Lab 4 and the data is consistent for the remaining three laboratories. As can be seen from the data, approximately 80% of students agree or strongly agree that they enjoyed doing the PLAs and 10% neither agree nor disagree.

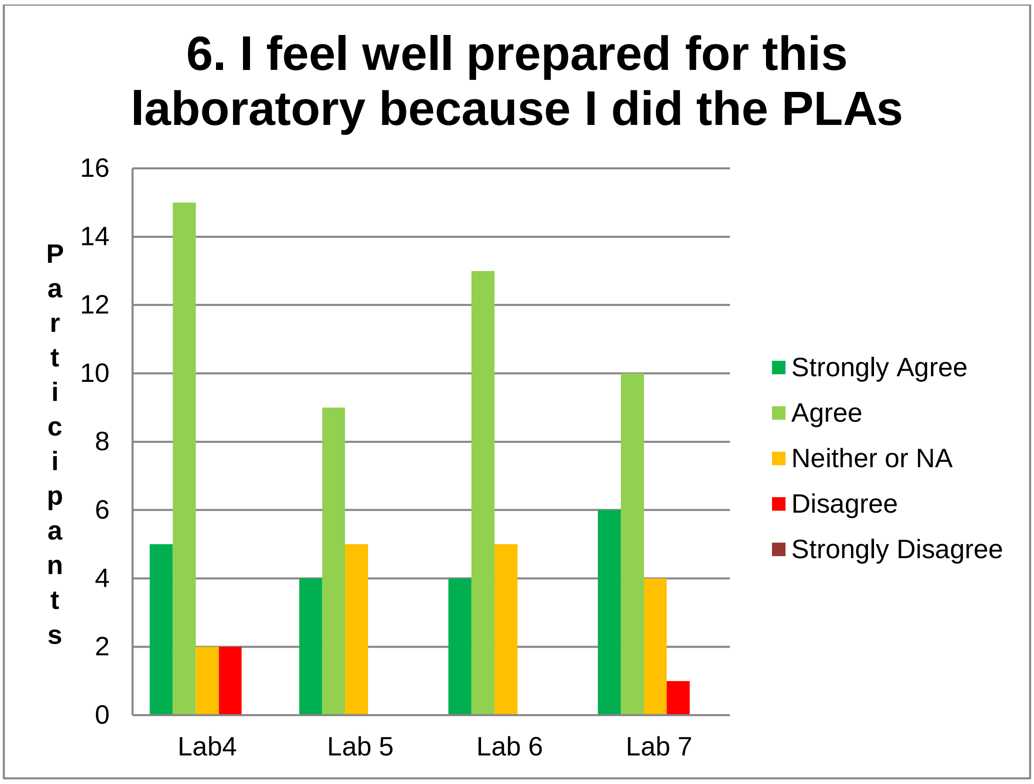

Figure 4.10 Responses to Statement 6 over the Four Weeks of Laboratories

Participants' responses to Statement 6, "I feel well prepared for this laboratory because I did the PLAs ", as shown in Figure 4.7 indicates 20% of participants Strongly Agree and 48% of participants Agree with this statement. 16% of students Neither Agreed or Disagreed with this statement and 3% of participants Disagree with the statement. No participants Strongly Disagreed. Figure 4.9 shows the actual number of participants' responses to Statement 6 over the duration of this research for the four laboratories. As can be seen from the data, the trend that approximately 70% of students agree or strongly agree that they felt well prepared for the laboratory because of the PLAs and approximately 20% neither agree nor disagree remains consistent over the four weeks. The next section presents the qualitative data findings for emotional engagement.

4.4.2 Qualitative Data Findings

The qualitative comments in the questionnaire were analysed and the findings are presented below. The open-ended comments were written by participants in response to a request to explain their choices to the quantitative statements. Themes were identified and colour coded as outlined in section 4.2 and the frequencies of a positive or a negative emotion was documented. Data given in response to the questions in the Focus Group were also analysed.

The main sub-theme apparent under the theme of Emotional Engagement was that of the value students attributed to the PLAs to help their learning. As shown in Figure 4.11, 30% of the participants' qualitative responses in the questionnaires were in relation to the value and helpfulness of the PLAs to participants learning. 24% of participants' comments agreed the PLAs were of value and they helped their learning. Examples of the comments given are highlighted here; "It is very useful to see it done beforehand"; "It allows me to feel refreshed coming in after a few days of no Interface" and "the video helped me to see how the circuit was built". 6% of participants disagreed that the PLAs were valuable and/or helpful. Here is a sample of the negative comments given by participants; "It was like homework"; "It was the same as the notes" and "time consuming".

The positive value of the PLAs to help their learning was strongly evident in the discussions by participants during the Focus Group. All five of the participants gave a strong statement regarding the value they placed on the PLAs to assist their learning. Participant E "found the PLAs very valuable" as going into class "with the additional knowledge" helped his understanding and his ability to "take measurement correctly". Participant A found Tinkercad valuable, as it helped acquire "the basic knowledge you need to know". The three other participants indicted that the PLAs were very valuable "as a revision tool" and Tinkercad allowed easy access to previous circuits so "studying" was made easier. Participant D attributes the PLAs to his success in the Skills Lab exam, "I used all the pre-labs again, and I did well in the skills lab because of that."

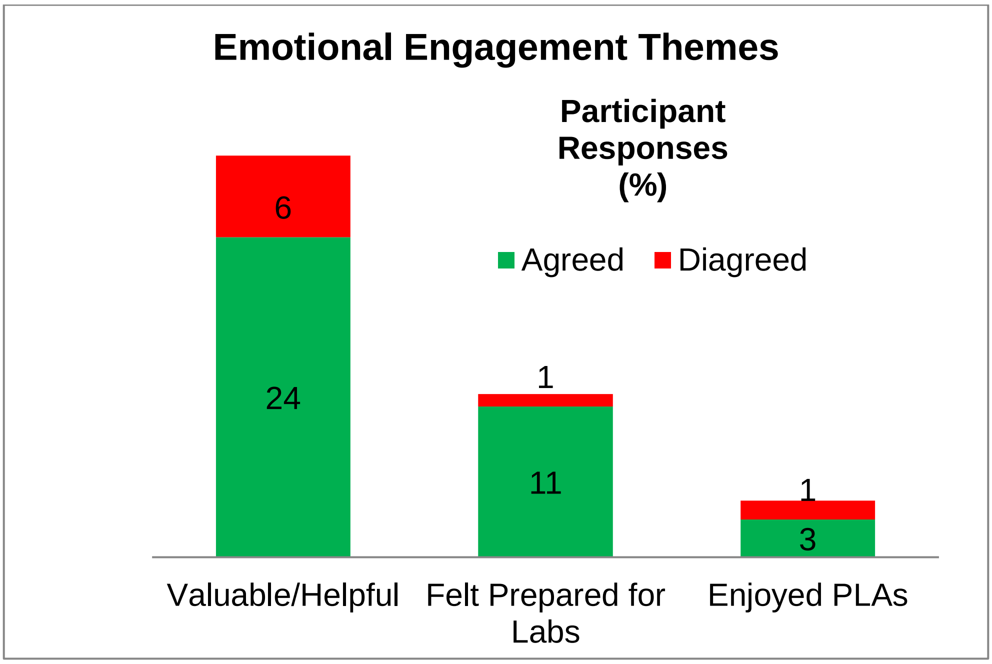

Figure 4.11 The Qualitative Themes and Responses from Questionnaire.

The next significant sub-theme identified was comments related to how the PLAs prepared participants for the laboratory work. As shown in Figure 4.11, 11% of participants made a positive comment in relation to the ability of the PLAs to prepare them for their laboratory work. Examples of positive comments are; "Seeing [the PLAs] before class gave me a good idea of what to expect"; "Additional preparation helps me understand the topic better" and "it helps to prepare for class, to be engaged in class". 1% of participants' comments were negative. Examples of negative comments are; "Not well prepared, have an idea" and "I could have been more prepared if I used Tinkercad".

Data from the Focus Group indicates that the participants believe the PLAs did help them to prepare for the labs and they link this feeling of preparation to improved confidence in their abilities to carry out the laboratories successfully. Participant C states, "I am much more confident going in" and Participant E indicates confidence in his ability to prepare for skills exam "... know I'm definitely going to be able to do that".

The feeling of preparation by using the PLAs leads to more independent self-directed learning as outline by Participant D “I didn’t need you holding my hand every time”. This feeling of empowerment is also demonstrated by Participant A who notes “I felt very comfortable using the [equipment], not like I’m going to blow things up”. Participant E also indicated by preparing him for laboratories the PLAs helped to manage negative emotions like “getting stressed and worried”. Similarly, Participant B also outlines how the PLAs help him feel much better prepared and knowing he “will not be shocked and not knowing what to do”.

The final sub-theme identified from the qualitative comments in the questionnaire was in relation to participants’ enjoyment of the PLAs. 3% of comments were positive and examples are; “I enjoyed the interactivity of Tinkercad”; “I'm enjoying them and have a better understanding of the module” and “It was fun working on Tinkercad”. 1% of participants’ comments expressed a negative emotion in relation to their enjoyment of the PLAs. Examples of the negative comments are; “It was useful, but I wouldn’t describe as enjoyable” and “I didn’t enjoy but saw the value”.

Data from the focus group supports the quantitative finding that 60% of the participants enjoyed doing the PLAs. Here the “drag and drop” interactive function in Tinkercad was described as “fun” by Participant E. Participant C attributes an increased enjoyment in learning from using the video and Tinkercad as opposed to just reading notes. Also, an important point made by Participant D was that using the PLAs made it “easier to understand the subject” and this led to an increased “enjoyment of the subject” and it “stopped me getting fed-up with the subject”. However, Participant D also indicated that building circuits on Tinkercad is “slightly repetitive after a while” and this was noted as a challenge with the PLAs, with a suggested improvement being that the Tinkercad circuits could be provided complete to students. The findings for the theme of cognitive engagement are addressed in the next section.

4.5 Findings for the Theme of Cognitive Engagement

Cognitive engagement, as detailed in Chapter 2, is the degree to which students approach learning and expend mental effort to comprehend and master content. This section will look at the findings for participants’ cognitive engagement with the PLAs and laboratory learning. The Likert responses to Statements 4, 5, 7, 9 and 10 from the questionnaire, as shown in Appendix 6 are presented.

Statement 4, “The PLAs helped me understand the theory for this lab” and Statement 5, “The PLAs helped me understand how to build the circuit and take measurements” were collected in the pre-laboratory questionnaires and collect data on students perceptions of how the PLAs helped with their knowledge construction prior to doing the practical. Statement 7, “I feel the PLAs prepared me to complete the tasks independently or with minimal help” collected participants’ perceptions of how the PLAs impact their persistence to learn, after they completed the practical. Statement 9, “I understand the theory and I can explain how this circuit works” and Statement 10, “I can build this circuit and take the required measurements” collected participants’ perceptions of how the PLAs impact on their knowledge construction after having completed the practical.

4.5.1 Quantitative Data Findings

Figure 4.12 gives a summary overview of the participants’ quantitative responses to Statements 4, 5 and 7 from the questionnaire on a Likert scale of Strongly Agree to Strongly Disagree. This data provides information on participants’ opinions of how the PLAs help their learning and their ability to learn independently. It amalgamates the data over the four weeks of laboratories and the data is presented as a percentage.

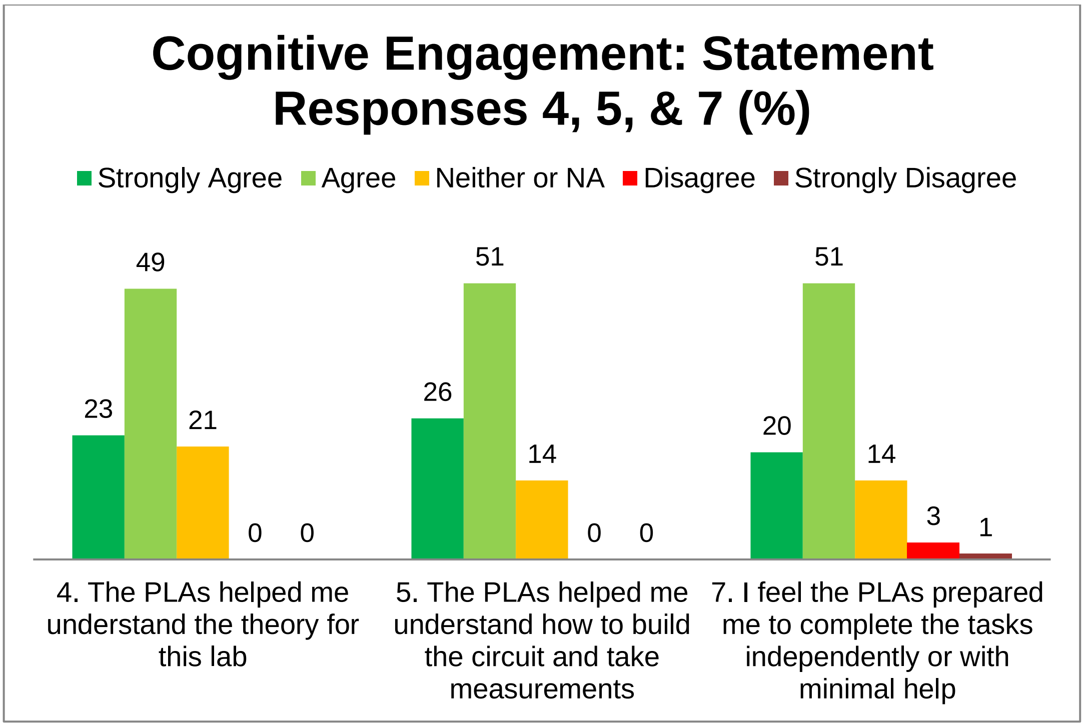

Figure 4.12 Responses to Statements 4,5 & 7 on Cognitive Engagement

Participants' responses to Statement 4, "The PLAs helped me understand the theory for this lab", as shown in Figure 4.12 indicate 23% of participants Strongly Agree and 49% of participants Agree with this statement. 21% of students Neither Agreed or Disagreed with this statement and no participants Disagree or Strongly Disagree with the statement. Figure 4.13 shows the actual number of participants' responses to Statement 4 over the duration of this research, for the four laboratories. As can be seen from the data, the trend that approximately 20% of participants strongly agree and approximately 50% agree that the PLAs helped them understand the theory for the laboratory remains consistent over the four weeks. There is little change over the course of the four weeks in the percentage of participants, approximately 20%, that neither agrees nor disagrees with this statement.

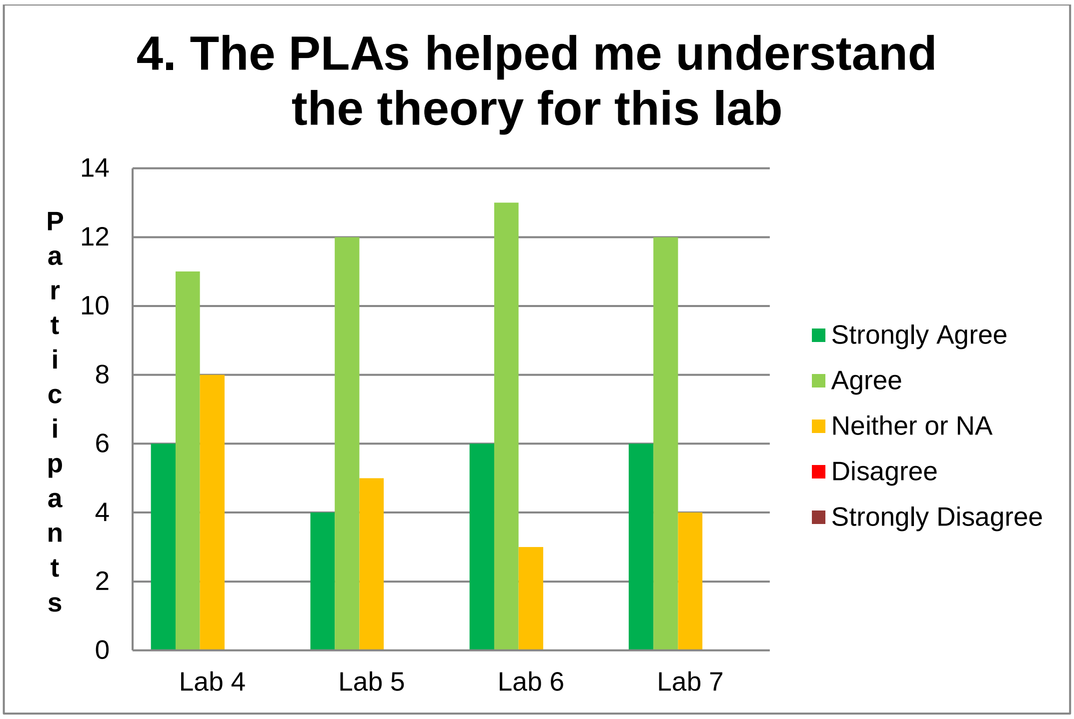

Figure 4.13 Responses to Statement 4 over the Four Weeks of Laboratories

Participants' responses to Statement 5, "The PLAs helped me understand how to build the circuit and take measurements", as shown in Figure 4.12 indicate 26% of participants Strongly Agree and 51% of participants Agree with this statement. 14% of students Neither Agreed or Disagreed with this statement and no participants Disagree or Strongly Disagree with the statement. Figure 4.14 shows the actual number of participants' responses to Statement 5 over the duration of this research, for the four laboratories. It shows, for Lab 4, approximately 40% of participants Strongly Agree with the statement. This drops by half to approximately 20% in the subsequent three weeks. The percentage of participants who Agree increased slightly over the subsequent weeks and those that Neither Agree nor Disagree remains consistent over the four weeks.

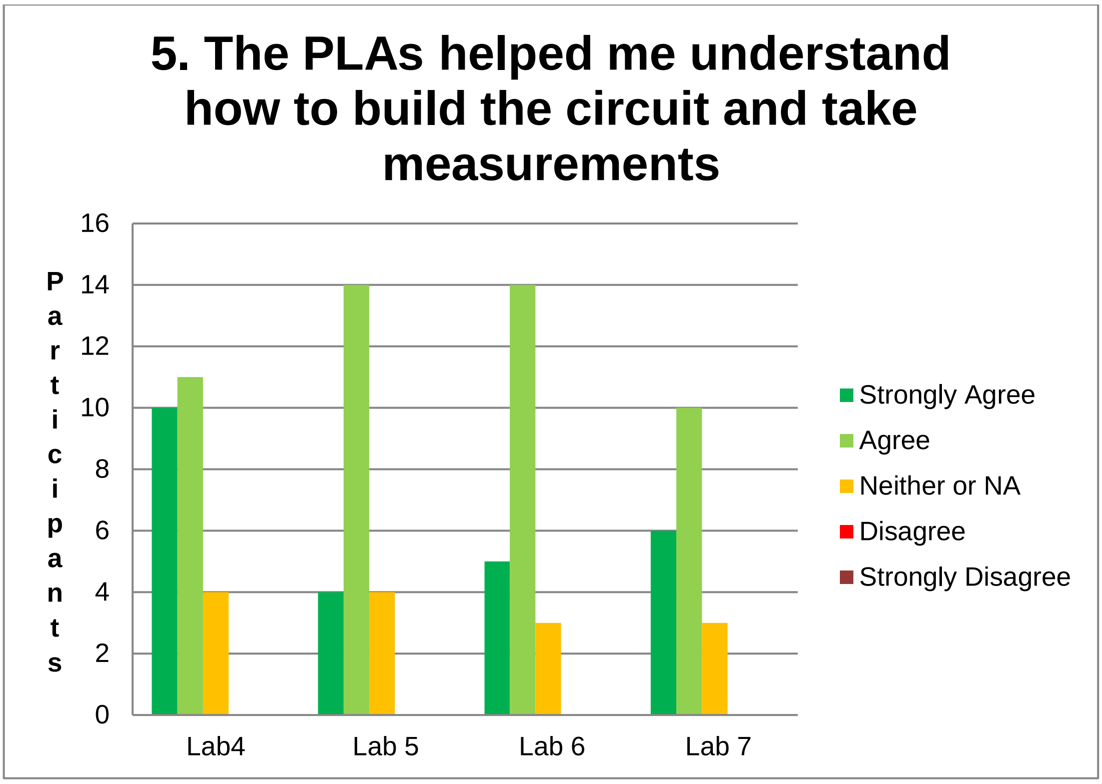

Figure 4.14 Responses to Statement 5 over the Four Weeks of Laboratories

Participants' responses to Statement 7, "I feel the PLAs prepared me to complete the tasks independently or with minimal help", as shown in Figure 4.12 indicate 20% of participants Strongly Agree and 51% of participants Agree with this statement. 14% of students Neither Agreed or Disagreed with this statement, 3% of participants Disagree and 1% Strongly Disagreed with the statement. Figure 4.15 shows the actual number of participants' responses to Statement 7 over the duration of this research, for the four laboratories. As can be seen from the data, the trend that approximately 70% of participants Strongly Agree or Agree that they felt the PLAs prepared them to complete the tasks independently or with minimal help, approximately 14% Neither Agree nor Disagree and approximately 3% Disagree or Strongly Disagree remains consistent over the four weeks.

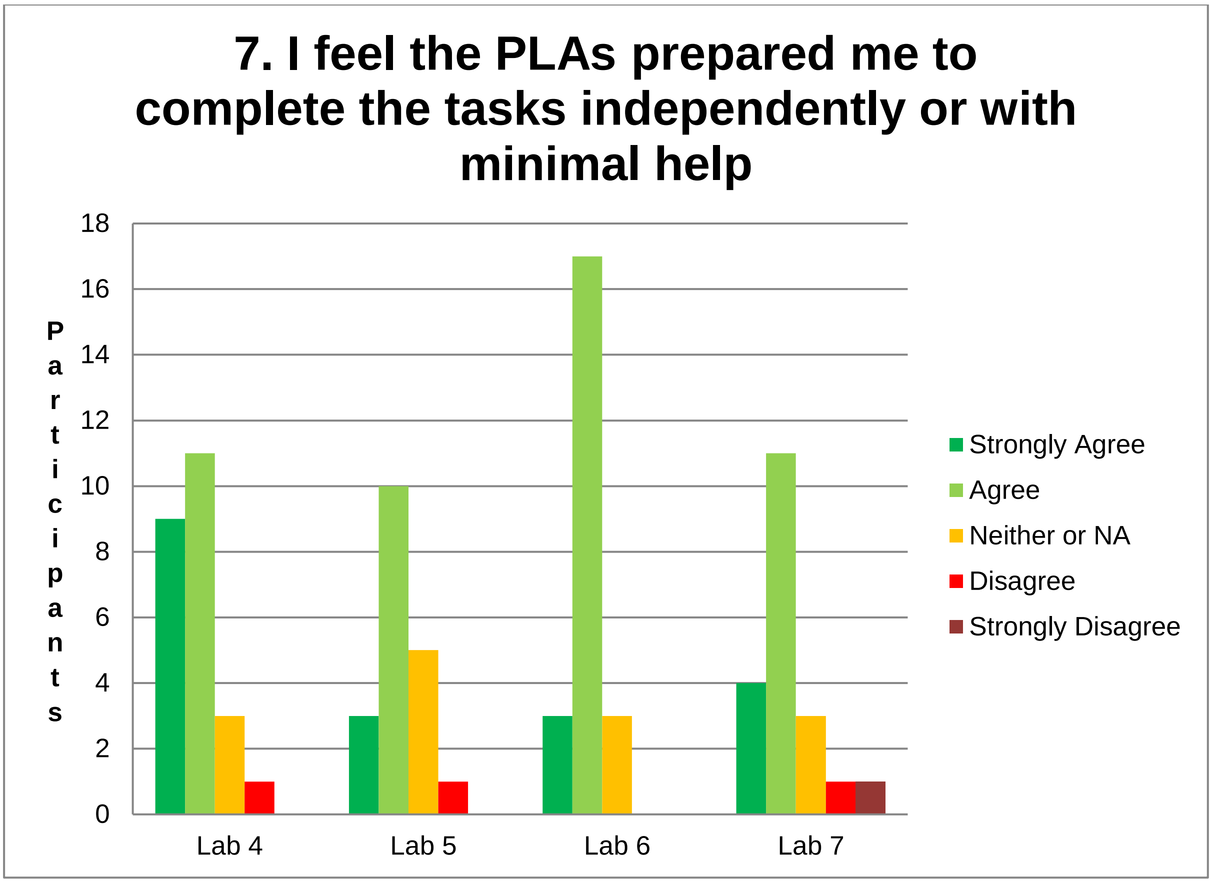

Figure 4.15 Responses to Statement 7 over the Four Weeks of Laboratories

Figure 4.16 gives a summary overview of the participants' quantitative responses to Statements 9, "I understand the theory and I can explain how this circuit works", and Statement 10, "I can build this circuit and take the required measurements", from the questionnaire on a Likert scale of Strongly Agree to Strongly Disagree. This data provides information on participants' perceptions of how well they understood the theory supporting the laboratory and their ability to build a circuit and take measurements after using the PLAs and completing the practical. It amalgamates the data over the four weeks of laboratories and the data is presented as a percentage.

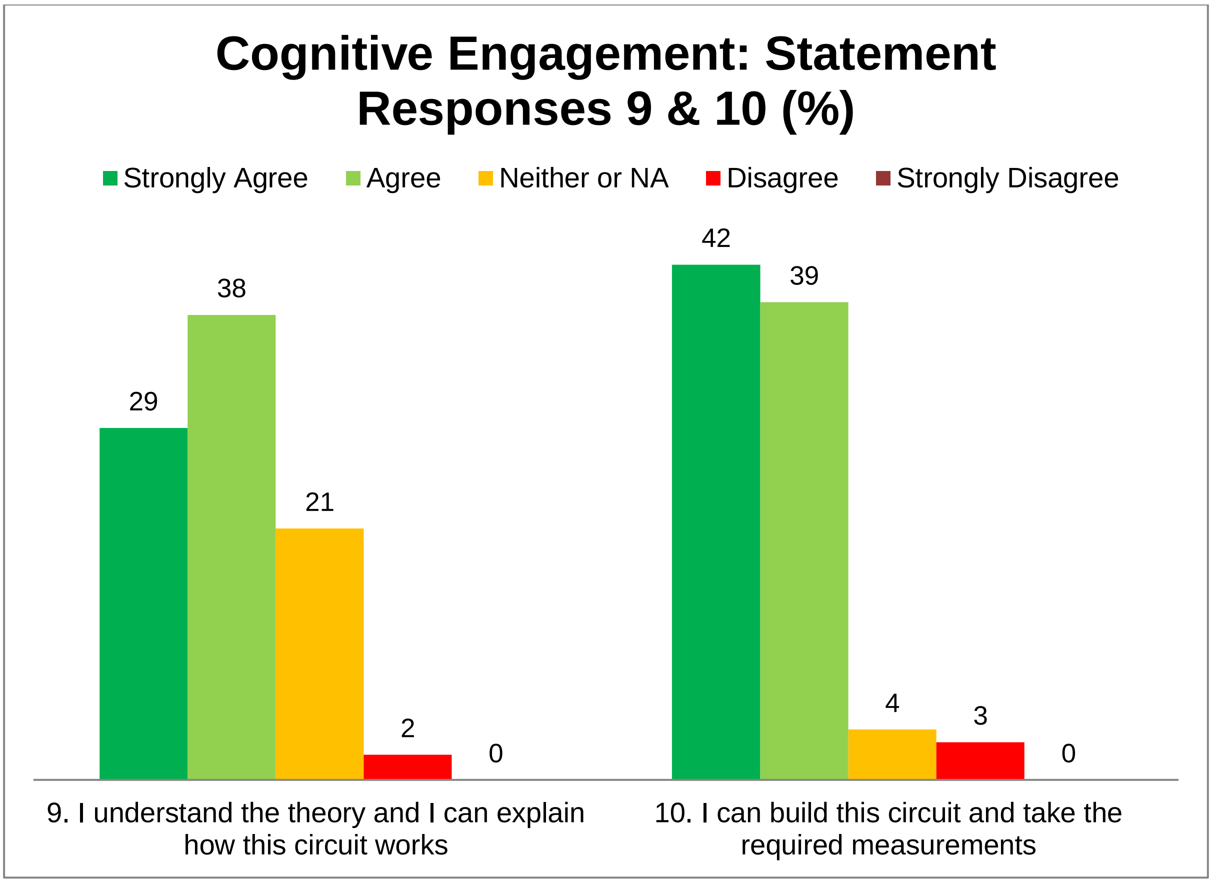

Figure 4.16 Responses to Statements 9 & 10 on Cognitive Engagement

Participants' responses to Statement 9, "I understand the theory and I can explain how this circuit works", as shown in Figure 4.16 indicate 29% of participants Strongly Agree and 38% of participants Agree with this statement. 21% of students Neither Agreed or Disagreed with this statement and 2% of participants Disagree with the statement. No participants Strongly Disagree.

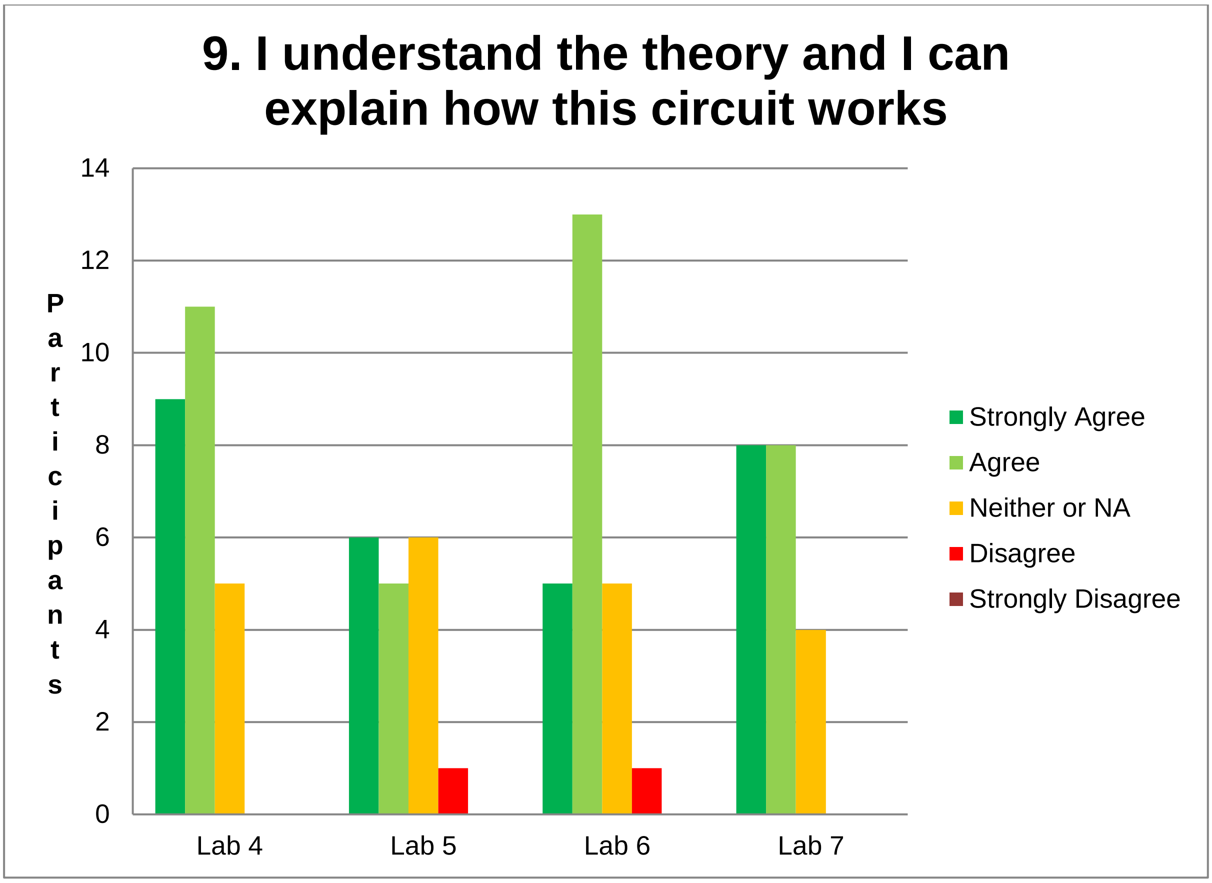

Figure 4.17 Responses to Statement 9 over the Four Weeks of Laboratories

Figure 4.17 shows the actual number of participants' responses to Statement 9 over the duration of this research for the four laboratories. As can be seen from the data, the trend that approximately 70% of participants strongly agree or agree and approximately 20% neither agree nor disagree that they understand the theory and I can explain how this circuit works remains consistent over the four weeks. There is some disagreement by participants with this statement for Lab 5 and Lab 6 only.

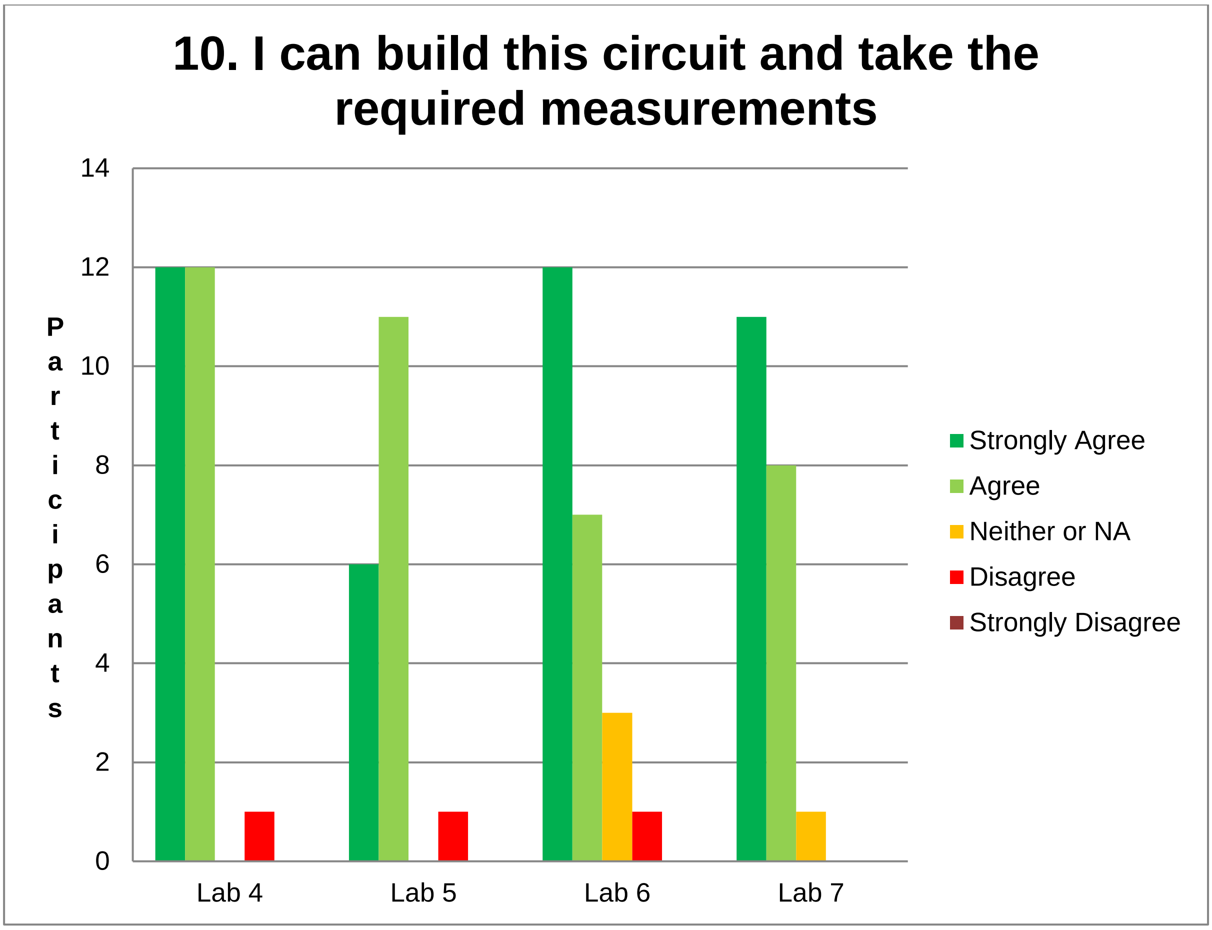

Figure 4.18 Responses to Statement 10 over the Four Weeks of Laboratories

Participants' responses to Statement 10, "I can build this circuit and take the required measurements", as shown in Figure 4.16 indicate 42% of participants Strongly Agree and 39% of participants Agree with this statement. 4% of students Neither Agreed or Disagreed with this statement and 3% of participants Disagree with the statement. No participants Strongly Disagree. Figure 4.18 shows the actual number of participants' responses to Statement 10 over the duration of this research for the four laboratories. As can be seen from the data, the trend that approximately 40% of participants Strongly Agree and 40% Agree remains strong over the four weeks, with a slight drop from Strongly Agree to Agree for Lab 5. The 3% who Disagree remains consistent for the first three laboratories and then for Lab 6 and Lab 7 there is an increase in those who Neither Agree nor Disagree with the statement. The next section presents the qualitative data findings for emotional engagement.

4.5.2 Qualitative Data Findings

As outlined previously, the qualitative comments in the questionnaire were analysed as discussed in section 4.2 and the findings for cognitive engagement are presented below.

The main sub-theme apparent under the theme of Cognitive Engagement was that of how the PLAs helped the participant with their “understanding”. As shown in Figure 4.19, 40% of the participants’ qualitative responses in the questionnaires were in relation to how the PLAs helped participants understanding of the material. 34% of participants’ comments agreed the PLAs helped their understanding. Examples of the comments given are highlighted here; “I could pause, reverse and understand everything slowly”; “The video showed step-by-step how to build the circuit”; “I found visual in Tinkercad much better than reading the theory” and “it built on what I had learned in lectures”. 6% or participants disagreed that the PLAs helped their understanding. Here is a sample of the negative comments given by participants; “I found it hard to follow”; “I struggled to grasp the theory” and “I just found it hard to explain how it works”.

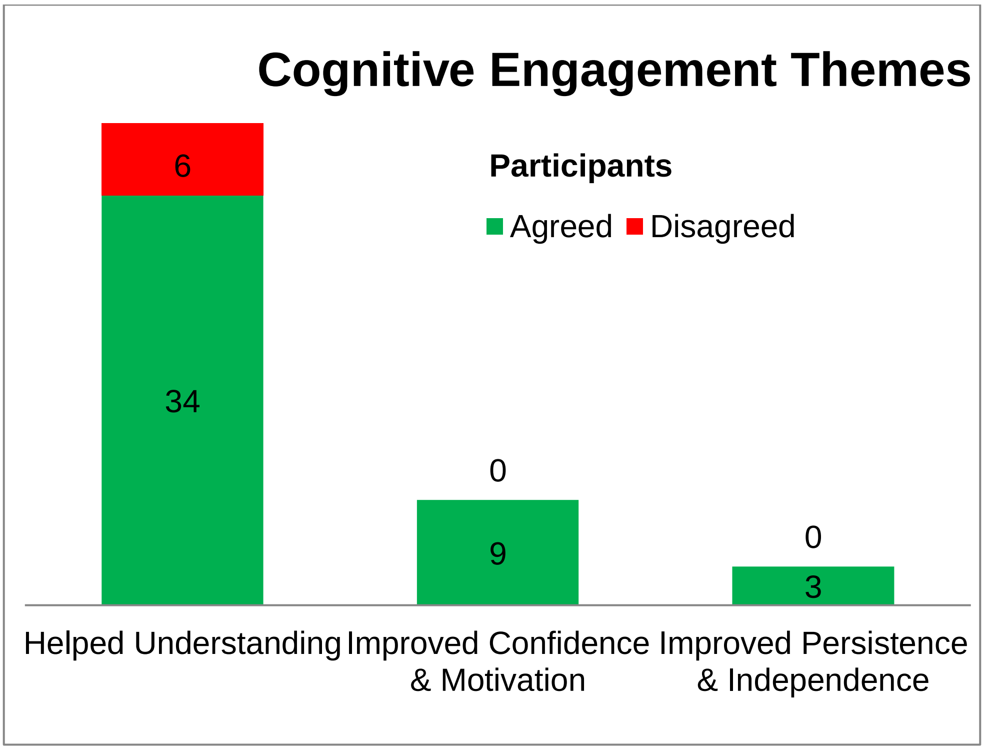

Figure 4.19 The Qualitative Themes and Responses from Questionnaire.

The Focus Group participants' feedback corroborated the questionnaire findings that the PLAs were a positive tool to help with their understanding and their learning. The data indicates that the PLAs enabled them to acquire a deeper understanding of the material. As discussed by Participant B "It's one thing to learn the formulas off ...but when you physically see the circuits and can substitute the numbers [into the formulas] it makes way more sense...I found that really helpful" and later he states "you feel like you are learning quicker and taking things in a lot better". Participant D also alludes to how the PLAs can promote deep learning as opposed to surface learning "I find if you're going into something blind [the lab], you will barely scrape through it without understanding it at all, you're not going to remember it the next day. If you have done the PLAs, you will know what you have done, and you can do it again if someone asks you". Participant D also attributes the direct link between theory and practice a significant aid to his learning "linking the theory to the circuit makes it easier to understand". Participant A and C suggest that being able to "experiment in Tinkercad" leads to improved learning and "contributes further to the understanding of the theory". Participant C liked the variety in the teaching methods and links this as a way to improve understanding "It's good to be taught through multiple different mediums, you taught us in class, come around to us, then on top the videos are just another platform, another way to try and understand". Participants indicate using multiple delivery methods also aids understanding, as noted by Participant D "The videos reinforce the theory you teach in class".

The next sub-theme identified was comments related to how the PLAs impacted on their confidence and motivation to learn. As shown in Figure 4.19, 9% of participants comments were related to improved confidence and motivation to learn. Examples of these comments are; "I am confident going into the lab"; "I found making the circuit easy after doing it on Tinkercad" and "previous labs I was unsure what to do". This theme was also discussed in the Focus Group and all inputs indicated a positive impact on participants' confidence and motivation to learn. As noted by Participant A "[The PLAs] motivated me a lot to build circuits…..but then I was experimenting, what if I put this resistor in, what if I put this capacitor in, what's the effect, what's the result?"

The final sub-theme identified was comments related to how the PLAs impacted on their ability to work independently and their persistence to learn. As shown in Figure 4.19, 3% of participants' comments were related to how the PLAs impacted on their ability to work independently and their persistence to learn. Examples of these comments are; "I worked through any issue I had"; "Although there were a few problems I was able to do most myself" and "I was able to operate mostly independently". Data from the Focus Group related more to how the PLAs gave them control of their learning. The ability to do the PLAs in their own time and to pause or re-watch the videos was noted as important for their learning. As stated by Participant A; "You can re-watch the videos so if you don't understand it on the first run, you can do it again and again until you get a better view." The easy accessibility of key content was also highlighted as important for control over their learning. As noted by Participant E, "with the videos and your Tinkercad circuits being saved on-line and easily accessible....... it means all the information you need is very easily findable; you know where to go for the exact information you need."

4.6 Conclusion

This chapter presented the key findings, which emerged from the quantitative data in the questionnaires and from the qualitative data from the questionnaires and the focus group. The findings were presented thematically in Section 4.3. In section 4.3.1, the quantitative findings show the PLAs impacted positively on students' behavioural engagement and the qualitative findings from the Focus Group add more insight into these findings. It concludes that participants indicate that after using the PLAs, they are more likely to attend the practical session and it encouraged more peer-to-peer interaction.

In section 4.3.2, the quantitative findings show the PLAs impacted positively on students' emotional engagement with most participants strongly agreeing or agreeing they enjoyed the PLAs, they saw value in the PLAs for their learning and that the PLAs helped them feel prepared for the laboratory. Again, the qualitative findings from the questionnaires and the Focus Group add more insight into these findings. A key insight is that participants found the PLAs very helpful for their learning by improving their confidence and they attributed the PLAs to managing negative emotions like boredom, stress and worry. In section 4.3.3, the findings show the PLAs have a positive impact on students' cognitive engagement. The findings conclude that the PLAs helped participants with their understanding, it improved their confidence and in turn, their motivation to learn. Chapter 5 analyses and discusses the main themes arising from these findings.

CHAPTER 5 : RESEARCH ANALYSIS & DISCUSSION

In this chapter, the research findings presented in Chapter 4 are analysed and discussed relative to the literature review in Chapter 2. This chapter supports the overall aim to evaluate the effects of flipped classroom PLAs on students' engagement with laboratory learning. The analysis and discussion of the findings addresses research Objective 5 outlined in section 1.2, namely, to analyse the research findings in conjunction with the literature to present recommendations for the next iteration of the action research cycle to transform teaching practice.

An adapted Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis will be applied to the findings presented for the dominant themes of behavioural engagement, emotional engagement and cognitive engagement in Chapter 4. A Strengths, Weakness and Suggestions of Improvements (SWS) model is used in a performance appraisal process (Palshikar, Pawar, Chourasia, & Ramrakhiyani, 2017). This model can be applied to a reflection on teaching practice, as is used in GMIT Letterfrack Teacher Education programme. The SWS analysis allows one to classify the strengths and weaknesses of the teaching intervention and to highlight suggested improvements to inform teaching practice. With support from the literature, it will highlight the key leanings for practice and identify what actions are needed to transform practise to improve student engagement. This model is closely aligned to the evaluate, analyse, conclude and action plan stages of Gibbs' Reflective Cycle discussed in section 3.6.3, and used to influence the design of the reflection journals for this AR study.

Section 5.1 analyses the strengths of the PLAs to enhance engagement. Section 5.2 analyses the weaknesses of the PLAs to enhance engagement and section 5.3 discusses the suggested improvements to the PLAs. The findings from the reflective journals are used to support this analysis.

5.1 Strengths of the Pre-Laboratory Activities

The data findings presented in Chapter 4 indicate that the PLAs had a predominantly positive impact on student engagement under the three main themes of behavioural engagement, emotional engagement and cognitive engagement.

Table 5.1 Strengths, Weaknesses and Suggestions for Improvement;
Analysis Applied to Chapter 4 Findings.

Strengths	Weaknesses	Suggestions for Improvement
Supports attendance	The PLAs were not clearly structured within the laboratory learning environment	Make PLAs a core component of the practical
Feeling prepared and sense of belonging		
Improves peer-to-peer interaction	No data on PLAs usage, among certain cohort of students	Needs a summative assessment element
Supports multiple delivery methods		
Multimedia video is a popular resource	Poorer engagement with Tinkercad	Improve engagement with Tinkercad
Valuable for learning	Despite the PLAs, other challenges remain with laboratory learning	
Improves confidence and motivation		
Supports self-directed learning		

The next sub-section analyses the key findings, which show the strengths of the PLAs as summarised in Table 5.1.

5.1.1 Pre-Laboratory Activities and Attendance

Firstly, as a key indicator of behavioural engagement, students' attendance at the laboratory sessions for Group A and Group B over the four-week research period is discussed. The findings, as discussed in section 4.3, indicate good attendance levels with 90% attendance levels for Group A. Group B has an average attendance of 75%. However, Group B attendance for Lab 7 shows a much lower attendance rate of 55%. It is important to note, that students who do not attend at least 75% of the module's laboratories without medical and/or sports certificates or other exceptional mitigating circumstances are required to 'repeat and attend' this module. This rule is in place to motivate students to stay engaged and to improve retention rates for first year students. It is unclear to what degree this rule or the addition of the PLAs can be attributed to the generally good attendance. However, there is evidence to suggest the PLAs have some influence on students attending classes and hence behavioural engagement. This is analysed further in the next sub-section.

5.1.2 The Impact of Pre-Laboratory Activities on Preparation and Sense of Belonging

A strong theme that came through from the findings was the fact the PLAs helped the participants feel better prepared for the laboratory. It would appear, that this leads to good engagement, as 82% of participants strongly agreed or agreed that “I was fully engaged (paying attention, actively involved etc.) during this laboratory”. It is notable that, data collected in the reflection journals correlates this finding that students are more actively involved, and it indicates improved student-teacher interactions within the laboratory environment. In the journal entry for Lab 4 Group B I note “Good engagement from students. Good contributions when I posed questions or asked for formulas to solve problems”. Participants suggest being “well prepared” and “knowing what we will be doing” also helped their sense of belonging in the laboratory. Participants state the PLAs “gave me a reason” to attend class and that they allowed them to “see the benefit” of attending class. They also refer to not feeling out of their depth “like an eeejit” and seeing “no point” attending. These feelings expressed by participants are examples of positive emotions and are consistent with research showing they lead to improved student engagement (Kahu, 2013; Wimpenny & Savin-Baden, 2013).

5.1.3 The Impact of Pre-Laboratory Activities on Peer-To-Peer Interaction

The impact of the PLAs on peer-to-peer interactions was very positive, as evidence in section 4.3.2. I have commented in my reflection journals that “good team-work noted” and “nice group dynamic”. This topic was discussed in the Focus Group and the participants indicate the PLAs improved their confidence and this in-turn leads to more collaboration between students as they are more likely to aid students who need help. This is a very interesting finding since social constructivism stresses the importance of collaboration among learners and it echoes Vygotskys’ “zone of proximal development”, where learning happens in collaboration with more capable peers (Fosnot & Perry, 1996; Matusov & Hayes, 2000). As Participant E states, “people learn better from their peers, so it works well”. Therefore, it can be concluded that the PLAs have a predominantly positive influence on peer-to-peer interactions and collaborations which are indicators of positive behavioural engagement and reflects social constructivist teaching strategies.

5.1.4 Pre-Laboratory Activities and Multiple Delivery Methods

The findings indicate that there was strong use and engagement with the PLAs over the four-week research period, with 83% of participants using the PLAs in one form or another and 82% agreeing that they were fully engaged, as evidenced in Figure 4.6. The PLAs include a multimedia video and an interactive on-line simulation tool, Tinkercad. Participants linked their sense of enjoyment of the PLAs to the fact they could learn through multiple mediums. They liked learning from the video and Tinkercad as opposed to just reading notes, as one participant explained "I found the visual in Tinkercad much better than reading the notes". This idea closely aligns to the principles of UDL and constructivism, both of which recommend providing multiple representations for students to draw on and therefore, supporting diverse learning styles (CAST, 2018; Jones & Edwards, 2010; Meyer et al., 2014).

The participants also indicated that multiple delivery methods lead to improved understanding. It would appear, watching the video and building the circuit in the simulated environment (Tinkercad) and then doing the practical, allows a student to grasp knowledge and subsequently build on this knowledge. This reflects Kolb's' well-accepted model of learning, that for learning to occur it must pass through a cycle of grasping knowledge and experiencing this knowledge (Abdulwahed & Nagy, 2009; Kolb, 1984; Mumford & Honey, 1992). Based on this evidence, it can be suggested that teaching strategies that support different learning styles are important to students and they do lead to better engagement levels. This finding is in line with other research, that shows teaching strategies that address a wide range of learning styles are more effective than traditional teaching methods which focus on a narrow range of styles (Felder & Brent, 2005).

5.1.5 Multimedia Video Resource

Watching the video was the most commonly used resource with 78% of participants watching it. The findings suggest participants like the videos as they allowed them to work at their own pace; "I could pause, reverse and understand everything slowly". In addition, the qualitative data indicated that participants found the videos easy to access on Moodle and they liked the structure of knowing exactly what they needed to study for the upcoming laboratory. As Participant E notes in the Focus Group, the PLAs "helped you study prior to class......the PLAs really helps you to focus on what you need to do" and Participant D states "without the PLAs I would have went into every class blind...just the handiness of having the information given to you every week". By working through examples, and giving guided instructions in the video, students appear to learn better. As discussed by Participant B "It's one thing to learn the formulas off ...but when you physically see the circuits and can substitute the numbers [into the formulas] it makes way more sense...I found that really helpful" and later he states "you feel like you are learning quicker and taking things in a lot better". This data supports the recommended design principles outlined in section 2.5.4 that PLAs should focus on supportive information, give learners an overview of the whole task and provide guided instructions (Agustian & Seery, 2017; Jones & Edwards, 2010).

The literature also indicates that to successfully motivate students to complete PLAs, they should be short, interactive and focused on key concepts (Karanicolas et al., 2016). The videos were approximately ten-minutes in length and participants indicated that this was a "good way to get information efficiently". The videos created for the PLAs use the lecturers own voice, employ a conversational style and Tinkercad allows information to be presented visually in real-time. The literature states these principles are important for good PLAs design and if met will foster positive attitudes towards the PLA resources (Agustian & Seery, 2017). As participants note "The video reinforces the theory you teach in class.....and then you link it to Tinkercad...it makes it easier to understand." The data indicates that 49% of participants used Tinkercad and those participants enjoyed the "interactivity" of Tinkercad, which is an important feature to encourage engagement. A discussion on the apparent lower use of Tinkercad will follow in section 5.2.3.

5.1.6 The Value of Pre-Laboratory Activities for Learning

On analysis of the findings on how the PLAs impact the participants' emotional engagement, a key sub-theme highlighted by participants was that of value and a key word that appeared was "helpful" for their learning. As the data in section 4.4.2

indicates, the key areas where participants saw the value in the PLAs were for "studying", as a "revision tool" and "going into class with the correct knowledge". It can be deduced, that one of the key reasons for participants' strong engagement with the PLAs is as a result of the value the PLAs have for their learning. This reflects findings found in other reports that students will not engage with PLAs if they do not consider them of value (Cann, 2016). Also, of importance, is participants indicated the PLAs helped to alleviate negative emotions like getting "stressed and worried" and prevented them getting "fed-up" with the subject.

5.1.7 The Impact of Pre-Laboratory Activities on Confidence and Motivation

Another strong theme that came through from the findings was the fact the PLAs helped the participants feel better prepared for the laboratory. Of note, is participants link this feeling of preparation to improved confidence in their ability to carry out the laboratory successfully and their motivation to learn. Participant E states "I just found being able to go into class feeling so confident about your ability and your understanding.... it gives a very positive mood, you go into class and you get everything done, you feel good about it and it encourages you to continue doing the PLAs and to continue learning." These findings are consistent with Von Glasersfeld's (1998) assumption that motivation to learn is strongly dependent on the learner's confidence in his or her own potential for learning. The findings suggest that the PLAs improve confidence which in turn motivates the students to learn. This finding is supported by other reports that indicate that PLAs lead to improved confidence (Cann, 2016; Whittle & Bickerdike, 2015). Mayer's (2017) recommended that PLAs should address the affective dimension to foster positive attitudes towards them and based on the evidence, it appears the PLAs do build confidence and motivation.

5.1.8 Pre-Laboratory Activities and Self-Directed Learning

Another theme that arose from the cognitive engagement findings was how the PLAs gave participants more control over their learning. The ability to control the pace of their learning by pausing and re-watching parts of the video was noted as beneficial. Participant A states, "You can re-watch the videos. If you don't understand it on the first run, you can do it again and again until you get a better view". The easy accessibility of key content was another factor that gave students more control as "the video and Tinkercad circuits were saved on-line...you know where to go for the exact information you need”. Another point that was common among the participants was that the structure of the PLAs encouraged them to take more control of their study as they had a specific and manageable task to “focus on”. Participant C states “The routine is good for helping you structure when you should be studying” and Participant E notes “...with the PLAs it really helps you to focus on what you need to do” and Participant D claims “Knowing exactly what you need to study every week is a lot easier than flicking through pages guessing what you need to know.” These findings support previous reports that highlight the importance of PLAs to foster independent learning (Chittleborough et al., 2007).

Also discussed earlier, the findings show there was strong links between feeling prepared, improved confidence and motivation to learn. Of significance for learning, is participants suggest this improved confidence leads to more independent learning and a feeling of empowerment as they feel more comfortable using the equipment and in their own abilities to learn. In support of this theory, the findings show that over 70% of participants indicate the PLAs helped them to complete tasks independently. It suggests the PLAs facilitate the participants to gain knowledge by doing the preparation work and they then have more confidence tackling real problems in the practical. These results are consistent with the view that these feelings of competence leads to a greater belief in students ability to solve problems and ultimately, develops persistence to solve new problems (Prawat & Floden, 1994). Considering the above, it can be deduced that the PLAs are an effective teaching strategy to encourage more self-directed learning. There is also good evidence to support the constructivist theory, that knowledge is constructed based on previous knowledge and experience (Blake & Pope, 2008; Carlile & Jordan, 2005; Hickman & Alexander, 1998)

5.1.9 The Impact of Pre-Laboratory Activities on Deep Learning

The analysis of the data findings for the theme of cognitive engagement show over 70% of participants believe the PLAs helped them understand the theory and helped them to understand how to build the circuit and take measurements, (see figure 4.12). The key theme emerging on analysis of the qualitative findings indicate the PLAs enabled the participants to gain understanding of the material and that doing the PLAs promotes deep learning as opposed to surface learning. These findings show strong ties to constructivist theory and CLT, discussed in section 2.5.3. The PLAs encourage active learning by facilitating students to develop understanding by building on existing knowledge and experience. Participant D attributes the direct link between theory and practice a significant aid to his learning "linking the theory to the circuit makes it easier to understand". Participant A and C suggest that being able to "experiment in Tinkercad" leads to improved learning and "contributes further to the understanding of the theory". These findings indicate that well designed PLAs that encourage students to spend time mastering key concepts will enable them to build on this and develop deep understanding. An important element of CLT, is that these PLAs will reduce the demand on student short-term memories (since they have mastered the key concepts) and therefore students' long-term memory will be improved (Van De Heyde & Siebrits, 2019). Interestingly, Participant D describes this scenario "I find if you're going into something blind [the lab], you will barely scrape through it without understanding it at all, you're not going to remember it the next day. If you have done the PLAs, you will know what you have done, and you can do it again if someone asks you". The evidence points to the fact that since the designs of the PLAs are based on the CLT guidelines and constructivist teaching strategies, they are an effective means of reducing cognitive load and promoting deep learning during laboratory classes. Based on this evidence, it would indicate that the PLAs do enhance cognitive engagement. The next section will analyse the weaknesses of the PLAs.

5.2 Weaknesses of the Pre-Laboratory Activities

The data findings presented in Chapter 4 indicate that the PLAs had a predominantly positive impact on student engagement and the previous section highlights the strengths of the PLAs. However, the findings also indicated that not all participants were as sure about the benefits of the PLAs under the three main themes of behavioural, emotional and cognitive engagement. This section discusses those findings and a summary is shown in Table 5.1.

5.2.1 Structure of the Pre-Laboratory Activities within the Laboratory Learning Environment

17% of the participants did not use the PLAs over the four-week research period. "Forgetting to do the PLAs" was given as the primary reason by participants for not doing the PLAs. This was highlighted in the Focus Group data, when participants noted a key challenge with the PLAs was remembering to do them. A weekly reminder was sent out to students via Moodle to complete the PLAs. However, this did not seem to be effective for all students as many students may not view their student email on a regular basis. Another possible explanation for non-engagement with the PLAs is that they were introduced for a four-week period in the middle of Semester One. Some students may not have viewed them as important to the overall laboratory learning process since they were not engaged with them from the start. As one participant noted "if it was a whole semester thing it would become a habit, but since it was only for four weeks, it was hard to get into the swing of it". This data supports the recommended design principles outlined by Agustian and Seery (2017) in section 2.5.4 that PLAs should be embedded in the overall laboratory learning process to encourage the student to see their value and engage with them. Bree (2017) reiterates this belief by stating they should be a "mainstream component of the overall practical experience".

5.2.2 Student Engagement with Pre-Laboratory Activities

While the findings from the participants show good engagement (>80%) with the PLAs this may-not be reflective of the actual usage in the laboratory. A key limitation noted for this study is the findings are only based on those students who were present and participated in the research. For example, for Lab 6 Group A, the data indicates that ten of the total students present (n=18) used the PLAs, two participants did not use the PLAs and there is no data for the other six students. An excerpt from my reflective journal for Lab 6, describing the laboratory mirrors this concern;

> About half the students didn't seem to be very comfortable using the formulas. I feel the engagement with the PLAs was poor this week and that students were not familiar with what they needed to know. I had to give a lot of individual instructions and guidance to half of the groups for them to be able to carry out the necessary tasks in this lab.

The PLAs were voluntary, and this may have been a deciding factor for those students who did not use them. Some participants indicated, if they were mandatory or had marks allocated to them, more students would do them. Even though many students saw the value and engaged with the PLAs, there is still a cohort who did not and need more encouragement. Section 5.3 outlines the suggestions to address this issue.

5.2.3 Student Engagement with Tinkercad

The data indicates that 51% of participants did not use Tinkercad. One possible explanation for the lower engagement with Tinkercad was participants did not feel it was necessary every week, as the video was enough. As noted by one participant "The video is always a help. I don't think Tinkercad is needed every week". As shown in Figure 4.7, 27% of participants neither agreed nor disagreed that they enjoyed doing the PLAs. Based on participants' responses, some of the reasons for this are they felt they were "time-consuming" and the "repetitive" nature of Tinkercad. The perceived challenge of the "repetitive" nature of building circuits on Tinkercad may explain the trend shown in Figure 4.4, whereby the use of Tinkercad dropped after the first week (Lab 4). When asked for suggested improvements to the PLAs, Participant D notes, "building circuits on Tinkercad is slightly repetitive after a while. I think if you had given us the Tinkercad [circuit] already made ....you could build it yourself but if you wanted to just see how it worked, you could do that as well."

Some participants attributed the fact that they had only watched the video and they did not use Tinkercad as the reason they did not feel prepared for the practical. This is an interesting point, as it suggests participants are open to using Tinkercad as they believe they would have been better prepared if they had engaged with this resource. It may indicate some limitations to the way Tinkercad is structured, as over half of the students were not motivated to engage with it. The video showed students how to build circuits using Tinkercad and they were then encouraged to build the circuit themselves using Tinkercad to prepare for the hands-on laboratory. However, there was no formative or summative assessment of students learning.

5.2.4 Other Challenges with Laboratory Learning

Despite the many benefits of the PLAs, it must be pointed out that the PLAs pose challenges for some students. 9% of participants are unsure that they saw the value in doing the PLAs for their learning with some noting they were "the same as reading the notes". This maybe reflective of the learning style theory model and it indicates that some students do not value additional teaching styles that offer visual and interactive resources and are happy with more traditional teaching practices. Despite this, the findings show a larger cohort of participants do value the variety in teaching methods and they are broadly in-line with previous studies (Felder & Brent, 2005).

The other main reason to explain why 27% of participants, as shown in Figure 4.7, were unsure they enjoyed doing the PLAs was they felt they were "time-consuming". As noted earlier, the videos were approximately ten-minutes in length and participants spent approximately ten-minutes doing the circuit in Tinkercad. While most students felt this was acceptable, the findings would suggest some students felt it may have been too long. Recommended guidelines for the design of PLAs in the literature, all suggest that resources should be kept short to promote engagement (Bree, 2017)

3% of participants disagreed that the PLAs made them feel well prepared for the laboratory while 16% of participants felt unsure that they felt well prepared. Some participants felt the PLAs helped them to feel "a little prepared" but not "well prepared". 21% of participants were unsure if "I understand the theory and can explain how the circuit works" while 2% disagreed with this statement. Some of the comments given by participants that provide insight into these feelings are; "I found it hard to follow"; "I struggled to grasp the theory" and "I just found it hard to explain how it works". In line with previous studies, this indicated that even with the additional resources, some students can still struggle to meet the demands of the challenging laboratory learning environment (Van De Heyde & Siebrits, 2019, p. 187). The next section discusses the suggestions to improve the PLAs.

5.3 Suggestions to Improve the Pre-Laboratory Activities

Section 5.2 highlighted some of the possible weaknesses of the PLAs to enhance student engagement with laboratory learning in the Interface Electronics module. This section outlines some suggestions to overcome these weaknesses and a summary is shown in Table 5.1. These suggestions are supported by the findings from the participants, the reflective journals and the literature.

5.3.1 Pre-Laboratory Activities and Core Components

In recognition of the recommended design principles outlined by Agustian and Seery (2017) and supported by Bree (2017), a suggestion going forward is to review the structure of the PLAs within the overall practical experience. The findings indicate that since they were only introduced for a four-week period, it did not encourage some students to see their value and engage with them. If the PLAs were part of the laboratory practical experience from the beginning students maybe more willing to see their value and engage more. Allocating marks to the PLAs would also help students to see their value. This is discussed in the following sub-section.

5.3.2 Pre-Laboratory Activities and Assessment

"Make them mandatory" was suggested as an improvement to the PLAs by some. This point was disputed by Participant E who felt the PLAs would no longer be viewed as a "helpful" resource but as "more work" if PLAs were mandatory. However, in light of the evidence and my professional experience, a key suggestion going forward would be to add a summative assessment element to get more students to engage with them. The students do an on-line Moodle quiz for the Interface Electronic module, but this is currently not linked to the PLAs. Going forward, a suggested improvement is to link this quiz to the PLAs and to add this on-line quiz as a summative assessment element to the PLAs. This would have the benefit of focusing students on the key concepts and helping them to assimilate the key information and address some of the challenges some participants found with the PLAs; "I can't say I have retained much information". Another suggestion in relation to the quiz, is to embed the quiz questions within the video to test students' knowledge. This method has the added benefit of forcing students to watch the video to do the quiz and I would have full visibility on who was using the video resource. This may be of benefit for further research in this area.

An additional benefit of the quiz, as found by Bree (2017), is it would highlight any gaps in student knowledge. These gaps in knowledge would be the focus for the teaching at the start of the next laboratory class, ensuring I was spending the time tackling those specific difficulties for students.

5.3.3 Tinkercad Use

While the previous two suggestions, namely, to ensure the PLAs are a core part of the practical experience and to add a summative element should improve engagement with the PLAs they do not specifically deal with the lower engagement with Tinkercad. The findings do support the fact that Tinkercad is an important tool, in conjunction with the videos, to improve students' learning. As the participants in the Focus Group who used Tinkercad note, being able to "experiment in Tinkercad" leads to improved learning and "contributes further to the understanding of the theory".

Based on my professional opinion, it would appear, the more motivated students built the circuit themselves in Tinkercad, whereas many others just watched the video which showed the circuit being simulated. Improving the engagement with Tinkercad is an important goal as the literature shows that getting students to actively engage is key to them constructing knowledge based on previous experience and what they are actively doing (Bruner, 1978; Chittleborough et al., 2007). Based on observations noted in my reflection journals after "asking for a show-of-hands of who used Tinkercad" it would appear that the students used Tinkercad less after the first week, and this is evident in the data for Group A, as shown in Figure 4.4. It may also explain why 40% strongly agreed in Lab 4 that "the PLAs helped me understand how to build the circuit and take measurements", but this dropped to 20% for subsequent laboratories, as shown in Figure 4.12 Going forward, a key suggestion is to include a specific assessment element that requires students to build the circuit and experiment with it on Tinkercad. An easy solution is to align this to the questions in the quiz. Alternative options may require students to produce evidence of the circuit they built before they complete the laboratory or to provide a worksheet that must be completed in tandem with the build.

As students build up their experience and expertise of building the circuits' in Tinkercad, an option for later laboratories is to provide students with the circuit pre-built. The learning outcomes for the pre-built circuits would focus more on applying existing knowledge to analyse and test relationships between variables to further understanding. It would also allow students to spend their time on higher-order learning, like "apply, analyse, synthesis" as opposed to "remember and understand", utilising the principles of Bloom's Taxonomy (Bloom, 1956; Loveys & Riggs, 2019). This would address some participants' perception that building circuits on Tinkercad was "repetitive". Recommended guidelines for the design of PLAs in the literature, all suggest that resources should be kept as short as possible to promote engagement (Bree, 2017). Another suggestion from participants was to add prompts in the video to work in tandem with Tinkercad. In further work, investigating ways to engage students better with Tinkercad could provide more insights.

5.4 Conclusions

This chapter analysed the data findings and discussed them with reference to the literature. Section 5.1 presents the strengths of the teaching intervention - in the form of the PLAs - to improve student engagement. It concludes that the key strengths of the PLAs were; it influenced attendance, promoted a sense of belonging to the class group, it offered diverse teaching strategies to support diverse student learning styles, it improved students' confidence and motivation which leads to more self-directed learning and it encourages deeper learning for students. These were discussed in-line with the literature analysis in Chapter Two.

Section 5.2 addresses the weaknesses of the teaching intervention in the form of the PLAs to improve student engagement. It shows there are still many challenges trying to get all students to engage with new interventions. It concludes that the structure of the PLAs within the module is an important consideration and that half the students did not engage with the Tinkercad resource.

Section 5.3 outlines some of the suggested improvements to try and address these challenges. In conclusion, adding summative assessments to the PLAs, ensuring the PLAs are clearly embedded in the over-all laboratory learning strategy and encouraging better engagement with Tinkercad are recommended as ways to improve the PLAs.

Chapter 6 provides a summary conclusion of this report and outlines the key recommendations.

CHAPTER 6 : CONCLUSIONS & RECOMMENDATIONS

6.1 Introduction

The primary aim of this study was to evaluate the effects of flipped classroom PLAs on students' engagement with laboratory learning for an introductory electronics module, Interface Electronics in the first year of a Computer Engineering degree at AIT. The chapter begins, in section 6.2, by restating the five objectives outlined in section 1.2 and providing conclusions in each case. Section 6.3 discusses the strengths of this research and reflects on the limitations of the study. Section 6.4 captures my own reflections on the research process. Finally, section 6.5 summarises the key recommendations for further practice and it identifies possible future research work in this area.

6.2 Research Objectives: Conclusions

This section will revisit the key objectives set out at the start of this thesis in section 1.2 and it provides a summary and concluding statement in each case.

6.2.1 Objective 1: To clarify key terminology relevant to this research; student engagement, flipped classroom, PLAs and AR

In this study, student engagement is defined relative to the research context as 'student involvement in the learning process'. This intentionally restricted working definition mirrors the fact that the study did not evaluate the role of external factors, like the campus environment on students' engagement. In conclusion, the model chosen to measure student engagement for this thesis was based on Schindler et al.'s framework which is detailed in Table 2.1 in Chapter 2. It measures student engagement according to three main themes; behavioural engagement, emotional engagement and cognitive engagement.

The flipped classroom is defined as a set of pedagogical approaches that move information-transmission teaching out of class, use class time for active and social learning, and requires students to complete pre- and/or post-class activities to fully benefit from in-class work. The PLAs are an evolution of the flipped classroom and the PLAs are defined as preparatory work students are required to carry out before a practical laboratory session. The PLAs in this study include a multimedia video and an interactive on-line simulation tool for electronic circuits, Tinkercad. In conclusion, the key terminology for this study has been clearly defined.

6.2.2 Objective 2: To critically evaluate existing literature relating to a flipped classroom teaching strategy in the form of PLAs with a view to informing the research design and analysis

In Chapter 2, a literature analysis was carried as outlined in section 2.2. Studies using on-line resources to prepare students for a practical laboratory element of a module in HEIs were critically reviewed. These studies, the authors, field of study and type of preparatory resources used are listed in Table 2.2. The literature concludes that PLAs are an effective teaching strategy to enhance learning but there are some challenges and PLAs cannot fully meet the demands of the complex laboratory learning environment. Chapter 5 concludes that the findings of this study come to a similar conclusion. It concludes that the PLAs are an effective teaching strategy to enhance student engagement but with further improvements to the PLAs, the engagement levels of more students could be enhanced.

6.2.3 Objective 3: To explore the learning theories underpinning PLAs with a view to informing the design of the PLAs

Section 2.5 concludes, based on literature evidence that the learning theories compatible with PLAs include; constructivism, learning style theory and CLT. It analyses how these learning theories and the recommended guidelines are enlisted to ensure the design and delivery of the PLAs for this study are underpinned by a strong pedagogical framework. The findings analysis in Chapter 5 was discussed relative to the literature review and it concludes that the recommended guidelines do improve the PLAs and ultimately, this leads to better student engagement with the PLAs.

6.2.4 Objective 4: To design and conduct cycle one of an AR study aimed at evaluating students' engagement with, and their perceptions of their engagement with, PLAs

Chapter 3 describes the research methodology and methods employed to meet the objective of this thesis. A summary is shown in Figure 3.1. An analysis of a few different research frameworks was undertaken to find the most appropriate approach to support the research objectives. In this research study, I as the lecturer-researcher identified a change - in the form of the flipped classroom PLAs – to transform teaching practice by improving student engagement with laboratory learning. This transformative element and the personal dimension that demands self-reflection are most closely aligned to an AR study. Therefore, it was concluded a mixed methods AR study was the most suitable framework for this research.

The data collection methods include student questionnaires, a focus group held with students and the capturing of my critical reflections in reflective journals. This enabled the research aim to be looked at from different perspectives. The findings from the AR study are presented thematically in Chapter 4, according to the themes of behavioural engagement, emotional engagement and cognitive engagement. Overall, based on the quantitative and qualitative findings, one can conclude that the PLAs have a positive impact on students' engagement with learning in laboratory environments.

6.2.5 Objective 5: To analyse the research findings, in conjunction with the literature, and present recommendations for the next iteration of the action research cycle

Chapter 5 analyses the research findings presented in Chapter 4 and discusses them in conjunction with the literature review in Chapter 2. A SWS reflection model, used in the GMIT Teacher Education programme is used to analyse the findings. It concludes that the key strengths of the PLAs were; it influenced attendance, promoted a sense of belonging to the class group, it offered diverse teaching strategies to support diverse student learning styles, it improved students' confidence and motivation which leads to more self-directed learning and it encourages deeper learning for students. The findings also indicated that there are weaknesses with the PLAs and not all students will engage with them. In addition, half the students did not engage with the Tinkercad resource. It concludes that the structure of the PLAs within the module is an important consideration. Section 6.5 addresses the recommendations arising from this study and the next section discusses the strengths and limitations of this study.

6.3 Study Strengths and Limitations

A key strength of this study is that it concludes that the PLAs have a positive influence on student engagement. This is a very important finding for students studying in AIT, as the literature shows clear links between improving student engagement and factors like student satisfaction, retention and academic achievement (Fredricks et al., 2004; Günüç & Kuzu, 2014; Kahu, 2013; Schindler et al., 2017; Zepke, 2014). Moreover, the literature thematic analysis gives coherence to the whole study. Other strengths include the appropriateness of the AR methodology and the data collection tools to achieve the research objectives. As outlined in section 6.2, this research achieved the aims and objectives set-out in section 1.4. In addition, the students' voice is at the forefront and it's their experience of the PLAs that is crucial to determine the impact on engagement levels. Finally, another strength of this research is that it offers recommendations to further improve practice and it builds on the existing body of research in the area of preparation of resources for laboratory learning.

There were a few limitations in this study. Section 1.4 outlined some limitation prior to commencing this research. This research only considers the perspectives of students from a first-year introductory electronics module, Interface Electronics at AIT and this group size is relatively small (n=24). The suitability to compare to other modules would need to be considered in relation to the specific learning outcomes of the module. In addition, there are a number of limitations that are apparent upon critical reflection of the research process.

The first limitation noted is that the participants in the Focus Group were based on volunteers and not a random selection of students. This has potentially led to some bias, as those students who volunteered are most likely the more motivated students (and they all had used the PLAs) and therefore is possibly more representative of a more engaged student. However, the ethical requirements for voluntary participation supersede this possible limitation.

Additional limitations were found using the paper-based anonymous questionnaires. Since they are anonymous, it was not possible to verify identity in any way. This anonymity was important from an ethical perspective; however, a limitation was people who should be excluded from the research may in fact have participated. There were some students in the group who were not eligible to participate since they were under eighteen years old. This possibility and ethical concern were mitigated by giving clear and detailed instruction to the students each week that if they were under eighteen years old, they were not eligible to participate. They were also reminded that participation was completely voluntary.

Another limitation was the responses to the open-ended questions were low. These qualitative responses were expected to provide detailed and valuable data from all the participants. It was found that approximately 50% of participants did not provide any qualitative data to questions and approximately 10% skipped a question and left it blank. An on-line questionnaire may be an alternative option in future studies. It could ensure participants fully answer a question before proceeding to the next one thus providing a more complete data set. While higher engagement with the qualitative data is desirable to provide more insight, it does not affect the quality of the data collected. In the next section, I reflect on this study.

6.4 Self-Reflection

The main aim of this research was to evaluate the effects of flipped classroom PLAs on students' engagement with laboratory learning in a HE AR study. Working as a lecturer in AIT, teaching laboratory-based modules and having many years of industrial experience, I am keenly aware of the importance the laboratory learning environment holds for the learner. The laboratory environment is where learners get to put theory into practice and to acquire the necessary skills graduates need for the workplace. I also have first-hand experience of the challenges faced by many students to grasp difficult concepts during this allocated laboratory time. This is compounded by the fact many students come to the laboratory unprepared and by the limited access to equipment outside of the allocated laboratory time. It was my wish, to make additional supports - in the form of PLAs- available to students to help them engage better with their laboratory work. This study looked at cycle one of an AR study, and a key learning for me was that the students benefitted from the structured stream-lined learning experience the PLAs provided. Many found the fact that the PLAs focused them to study specific content for a fixed time, using the different methods of video and Tinkercad, promoted their understanding and confidence and ultimately their learning. Another key transformation for me, was I learned the value of getting feedback from students on my teaching methods. Before this research, I did not ask for student feedback on my teaching strategies, but I was very impressed with their insightful contributions to this study.

My dual role as researcher and lecturer was an important consideration during this research process and I had to consciously reflect on this position throughout all design stages of this process. This process of self-reflection allowed for analysis of my attitudes, feeling and observations to ensure rigour and ethics were at the forefront of all decisions and actions. For example, as noted in my Journal entry for Lab 5, Group B;

> There was less questionnaires (n=14) handed in today than the number that agreed to participate (n=19). This was disappointing. Other than encouraging the group next week to submit their questionnaires, I feel there is little I can change given that the students fill in the questionnaires anonymously and voluntarily.

At the start, the voluntary nature of this research was explicitly highlighted to ensure no student felt pressurised to partake due to the power imbalance caused by my insider-researcher role. Another key element to mitigate this power imbalance was to use anonymous questionnaires, encouraging students to freely express their opinions and criticisms without any fear of it having a negative impact on their grades for example. I believe, as evidenced in the findings, participants felt comfortable to communicate their opinions and perceptions of the PLAs and to give their experience of how the PLAs impacted their engagement with learning throughout this study. The next section discusses the recommendations for future practice and future research.

6.5 General Recommendations

This section outlines the recommendations that were developed during the analysis of the research findings for future teaching practice and for future research studies.

6.5.1 Recommendations for Future Practice

The findings strongly indicate that the PLAs had a positive impact on students' engagement across the three main themes of behavioural engagement, emotional and cognitive engagement. The participants in the study highlight several benefits they bring to their learning experience. As a lecturer, I found the PLAs led to good engagement levels and improved levels of understanding among students. This aligns with the literature which also supports PLAs as an effective teaching strategy to promote engagement and that this increased engagement leads to better academic performance and increased student retention rates. As a result, I would strongly recommend the PLAs as a worthwhile intervention to any practical module.

The findings also indicate that there are still challenges getting most of the student group to engage. Considering this, I would recommend that the PLAs are embedded in the laboratory process from the start, so students view it as a key component of the practical work. In addition, another key recommendation for future practice is to add a summative element to the PLAs and therefore, encourage more students to use them. This is important, as the data suggests they are very beneficial for students' engagement, learning and understanding. A potential option is to link the PLAs to a summative on-line quiz.

The findings highlight that the engagement with the on-line simulation tool, Tinkercad was less than those who used the video. A recommendation going forward is to improve student's engagement with Tinkercad as the findings suggest that those who did use it, felt better prepared for the laboratory. One possible suggestion is to provide further guided instructions to students on using Tinkercad and link this to the summative element. For example, provide a worksheet with questions that requires the students to build the circuit before they can answer the questions. Another important element is to scaffold the students learning experience, to balance what some students felt was the repetitive nature of building circuits on Tinkercad. As the students learning develops, one possibility is to provide the students with the circuits pre-built and to focus on higher order learning concepts like experimenting with variables to see the impact on the circuit. It is hoped these recommendations would encourage further use of what was found to be, a valuable learning tool to promote better understanding of electronic circuits.

6.5.2 Recommendations for Future Research

This study looked at the first cycle of an AR study in-line with the available time. Further research work could consider how the key leanings and recommendations outlined above could be implemented and evaluated in the next cycle to develop teaching practice further. Special attention could be given to the use of Tinkercad and how best to use it to encourage better student engagement. Also, the reflective element of this research could be further developed to provide more insights.

In future research, it would be beneficial to get deeper insights from those students who were not using the PLAs and to determine the reasons for this. Ideally, a focus group design would have representatives from students who used the PLAs and those who did not. However, as experienced in this study, those who volunteered to partake in the Focus Group were those who had used the PLAs.

To conclude, I believe this thesis makes a valuable contribution to the understanding of how PLAs can be designed or altered to the needs of undergraduate engineering students, to enhance their engagement with laboratory learning. The key recommendations for future teaching practice are; that the PLAs are a worthwhile intervention to improve student engagement but they need to be clearly structured within the curriculum design from the start, to ensure student buy-in; that the PLAs should be linked to a summative assessment element to encourage greater use and that Tinkercad needs to be better integrated in the module design to encourage more use of this resource. One cycle of an AR study was completed in the study, in line with the available timeframe of this study. Nonetheless, this is an area I would like to continue investigating and I intend to implement the recommendations in my practice to further develop my teaching practice and encourage engagement from all students to benefit their lifelong learning.

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Appendix 1: Pre-Laboratory Activities

Figure A shows a screenshot of the Interface Electronics' Moodle page showing the PLAs resources.

Link to Tinkercad; on-line circuit simulation software.

https://www.tinkercad.com/

Link to the videos created for students as part of their PLAs. The videos explain a topic by using Tinkercad to build and take measurements of a circuit and link this to theory.

Laboratory 4:

Video 4: Resistors in Series and Parallel

https://youtu.be/QluGM-8gXFc

Laboratory 5:

Video 5: Resistors in Series & Parallel - Measure current

https://youtu.be/lsJVG7kD2EA

Laboratory 6:

Video 6a: Voltage Divider using POT

https://youtu.be/bD-bkHN0NlM

Video 6b: Voltage Divider using LDR

https://youtu.be/oRjiFUtzWJQ

Laboratory 7:

Video 7: Kirchhoff's Voltage Law

https://youtu.be/dSNQdSvNVSI

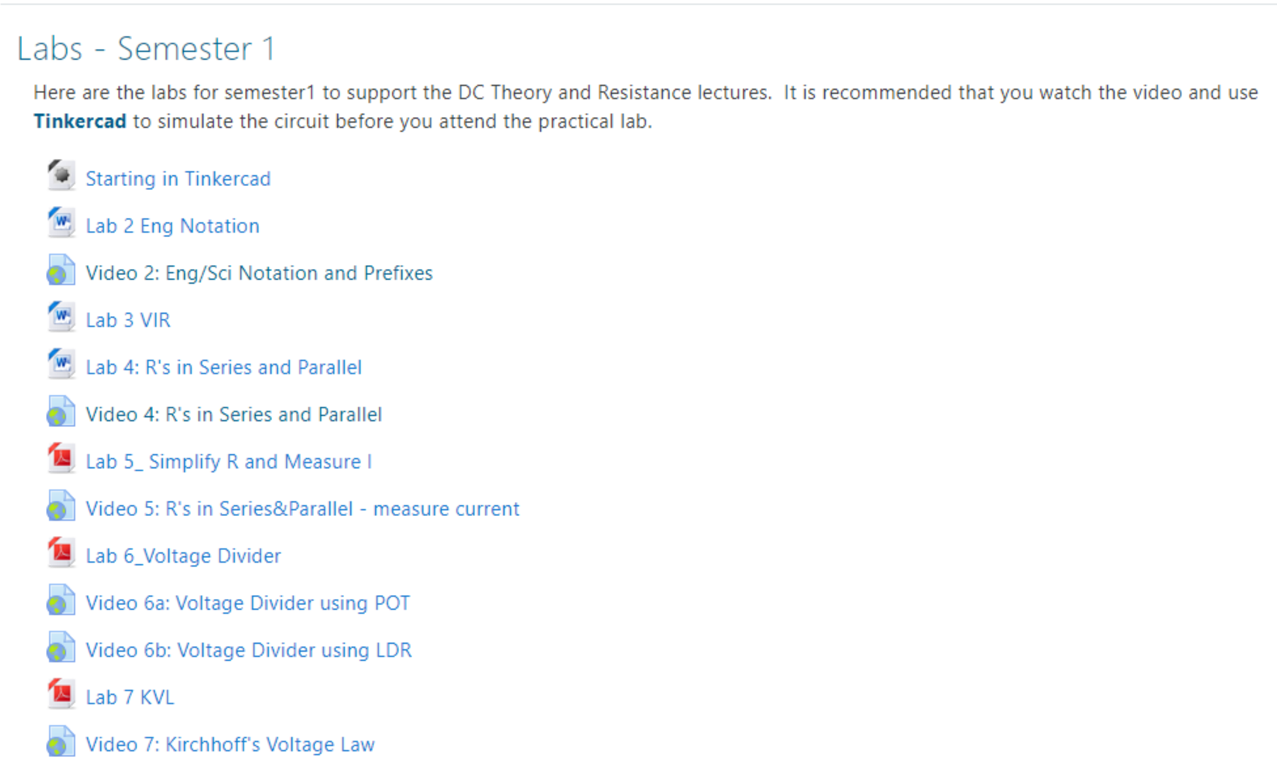


Figure A. Screenshot of Interface Electronics' Moodle page showing PLAs.

Appendix 2: Participant Information Leaflet

1. **Title or working title of the study:** An Evaluation of the Effects of Flipped Classroom Pre-laboratory Activities on Students' Engagement with Laboratory Learning: A Higher Education Case Study.

2. **Introduction to the study:** The study will be conducted on the laboratory practice in the Interface Electronics first year module of the ICT and BEng in Computer Engineering degree in the Electronics and Informatics Department at AIT. In order to enhance student engagement, pre-laboratory activities will be applied to the Interface Electronics module. The pre-laboratory activities include watching multimedia videos and using an interactive simulation tool, *Tinkercad*. This research will evaluate if the pre-laboratory activities promote student engagement.

3. **Research Procedures:** Three data collection methods will be used to collect information. The first method is student surveys. These will include both qualitative and quantitative questions. The second method is a student focus group. You may be requested to join a group discussion with 6-8 students to give your feedback on using the pre-laboratory activities. An audio recording of the data from focus groups will be taken. The third method is a researcher's journal where the researcher will note her reflections on the learning experience.

4. **Benefits of the research:** It is the aim that the information provided by participants will improve students' laboratory learning experience for the Interface Electronics module.

5. **Risks of the research**: There are no material risks, discomforts or side effects associated with this research.

6. **Exclusion from participation**: You cannot participate in this study if you are under 18 years of age.

7. **Confidentiality:** 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 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 your participation in the study at any time without your consent.

11. **Permission**: This research has approval from the MA in Teaching and learning Research Ethics Committee.
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 Theresa Costello who can be telephoned at 0906471839 or e-mail G00376138@gmit.ie.
13. **New Information arising:** If the researcher or members of the Research Advisor Panel learns 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.
14. **Data Storage:** All data will be stored securely – manual data in a locked cabinet and electronic data in an encrypted folder.

See the informed consent forms below.

Appendix 3: Informed Consent Form 1

The form given to students completing the questionnaires.

Project Title: An Evaluation of the Effects of Flipped Classroom Pre-laboratory Activities on Students' Engagement with Laboratory Learning: A Higher Education Case Study.

Principal Researcher: Theresa Costello

Background to the Study: The study will be conducted on the laboratory practice in the Interface Electronics first year module of the ICT and BEng in Computer Engineering degree in the Electronics and Informatics Department at AIT. In order to enhance student engagement, pre-laboratory activities will be applied to the Interface Electronics module. The pre-laboratory activities include watching multimedia videos and using an interactive simulation tool, *Tinkercad*. This research will evaluate if the pre-laboratory activities promote student engagement.

Three data collection methods will be used to collect information. The first method is student surveys. These will include both qualitative and quantitative questions. The second method is a student focus group. You may be requested to join a group discussion with 6-8 students to give your feedback on using the pre-laboratory activities. An audio recording of the data from focus groups will be taken. The third method is a researcher's journal where the researcher will note her reflections on the learning experience.

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 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 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 to:	**Yes**	**No**

use the data obtained from you in other future studies without the need
for additional consent.

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's 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's Name:

Contact Details:

Participant Signature:

Date:

Researcher's 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 have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

Signature:

Date:

Appendix 4: Informed Consent Form 2

The form given to students participating in the focus group.[1]

INFORMATION SHEET	
Purpose of the research study?	It is the aim that the information provided by participants will improve students' laboratory learning experience for the Interface Electronics module and contributes towards informing educators on how best to design flipped laboratory learning environments.
What will the research study involve?	Three data collection methods will be used to collect information. The first method is student surveys. These will include both qualitative and quantitative questions. The second method is a student focus group. You may be requested to join a group discussion with 6-8 students to give your feedback on using the pre-laboratory activities. An audio recording of the data from focus groups will be taken. The third method is a researcher's journal where the researcher will note her reflections on the learning experience.
Why have you been asked to take part in this research study?	You have been asked to participate in this study because you are a first-year engineering student who is studying the Interface Electronics module as part of your education.
Will your participation in the research study be kept confidential?	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?	The information gathered from this study will be presented as part of the results. As participant information is confidential, no identifying factors relating to participants will be in evidence in any reports.
What will happen to the results?	Upon completion of the project, results will be presented in a final thesis report and/or any disseminated research (i.e. conference papers and/or presentations, publications, etc.).
What are the 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.
What 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). In order to withdraw, you should contact the principal researcher, Theresa Costello who can be telephoned at 0906471839 or e-mail G00376138@gmit.ie.

[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.

Who 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: Theresa Costello who can be telephoned at 0906471839 or e-mail G00376138@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 5: Reflective Journal Template

Interface Electronics

Laboratory 7: KVL

REFLECTIVE JOURNAL

Group/Date	A (12/11/19)	B (13/11/19)
Date of Reflection		

Practitioner Reflection

The purpose of this reflection is to answer the questions:

- How did the introduction of PLAs impact on teaching?
- What were the observed levels of student engagement?
- What was learned about how the introduction of a flipped classroom strategy, in the form of PLAs, impact student engagement?

Description of laboratory environment	Critique your performance. How did you prepare the students for the laboratory practical? What activities did you do, and the students do? Did this change since you introduced the PLAs?

Feelings and/or Reactions	How did you feel the teaching went? How do you think students felt it went? What assumptions did you bring to the laboratory? How did these affect your teaching? What was your reaction to student engagement levels?

Evaluation of Student Engagement	Comment on your personal observations of engagement levels:
	What was good/poor and why?
	• Behavioural engagement.
	  ○ Participation
	  ○ Interaction levels.
	    ▪ Peer-peer collaboration.
	    ▪ Asking questions.
	• Cognitive Engagement
	  ○ Motivation/Persistence
	    ▪ Ability to debug.

	▪ Work independently. ○ Deep Learning. ▪ Quality of worksheets. ▪ Asking deep questions

Critical Reflection	What have you learned? Will you manage the next laboratory session the same way? What would you change in the laboratory or PLAs? What have learned about your assumptions and feelings and how this impact on student engagement?

Action plan	What next? Any adjustments you can make before next session? Any changes to feed forward to next cycle of AR?

Questions adapted from Gibbs's Reflective Cycle (1988), G. Costello et al (2015) work on reflection in action research and from Schindler et al.'s (2017, p. 5) conceptual framework of types and indicators of student engagement.

Appendix 6: Questionnaire

Interface Electronics

Laboratory 4: Resistors in Series and Parallel

PRE-LABORATORY STUDENT FEEDBACK

AIT Connect & Discover

Group/Date A (15/10/19) B (16/10/19)

Please answer these questions as fully as you can **BEFORE** you complete the laboratory.

1. How did you prepare for this laboratory? Tick as appropriate.

☐ I watched the pre-laboratory video.

☐ I used Tinkercad to simulate the circuit.

☐ Other. Please specify:____

☐ I did none of the pre-laboratory activities (video/simulation). Was there a reason for this? ____

- Read the statements below and **circle** the choice that most applies to you.
- If you **did not** use the pre-laboratory resources resume this survey at Q. 8 **after** you complete the laboratory.

2. I enjoyed doing the pre-laboratory activities.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____

3. I can see the value in doing the pre-laboratory activities to improve my learning.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____

4. The pre-laboratory activities helped me to understand the theory for this laboratory.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____

5. The pre-laboratory activities helped me understand how to build the circuit and take measurements.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____

6. I feel well prepared for this laboratory because I did the pre-laboratory activities.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____

Interface Electronics

Laboratory 4: Resistors in Series and Parallel

Group/Date A (15/10/19) B (16/10/19)

POST-LABORATORY STUDENT FEEDBACK

Connect & Discover

Please answer these questions as fully as you can **AFTER** you complete the laboratory.

7. I feel the pre-laboratory activities prepared me to complete the tasks independently or with minimal help.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____________________

8. I was fully engaged (paying attention, actively involved etc) during this laboratory.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____________________

9. I understand the theory and I can explain how this circuit works.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____________________

10. I can build this circuit and take the required measurements.

Strongly Agree Agree Neither Or N/A Disagree Strongly Disagree

Explain your choice: ____________________

11. Have you any suggestions to improve the pre-laboratory activities for this laboratory?

____

12. Have you any suggestions to improve the overall laboratory learning experience for this laboratory?

____

Thanks very much for your time and valuable contributions.

Appendix 7: Focus Group Email Invitation

Hi All,

You are invited to participate in a Focus Group on Thursday November 21st at 11am in X102.

The aim of the focus group is to gain as accurate a picture as possible of your experiences of using the PLAs and how these impacts on your engagement and learning. It is hoped the information provided by you will improve students' laboratory learning experience for the Interface Electronics module and contributes towards informing educators on how best to design flipped laboratory learning environments. The focus group will follow-on from the questionnaire, asking similar questions but allowing more time for discussion of these points.

The Focus Group will last about 40 to 50 minutes.

Tea, coffee and pastries will be available.

Please confirm your availability to attend. Thanks again for your time.
Kind regards,
Theresa.

Appendix 8: The Focus Group Structure and Questions

Discussion Introduction

1. Re-cap the purpose of focus group.

2. Outline the structure of the focus group:
    - Time: 40 to 50 minutes
    - Question themes.

3. Describe moderator role:
    - To ask questions and keep the group on track.

4. Describe participants' role:
    - Share experiences and opinions, both positive and negative.
    - No answers are right or wrong from participants.
    - Everyone participates.

5. Focus group ground rules:
    - Everyone will have a chance to be heard, with one speaker at a time.
    - The discussion is about your experiences of the PLAs and laboratory learning as part of the Interface Electronics module at AIT.

6. Audio recording/note taking
    - For the purposes of data collection, notes will be taken, and the focus group will be recorded.
    - No names will be used.

7. Open to participants questions on any of the above.

8. Focus Group discussion and recording.

Interface Electronics: PLAs		
Date	21/11/19	
Time	11am – 12pm	

Focus Group Questions

(Note-taking and audio recording begins)

Background of and general information about participants

1. Introduce yourself (participants. A, B etc. No names)
   State what course are you enrolled in and what group you are in?

Theme 1: Behavioural Engagement with PLAs

2. How did you use the PLAs?

   Prompt: Video and Tinkercad. /Video only/If none, why?

3. How do you feel the PLAs impacted the time and effort you spent learning?

4. What would encourage you to use the PLAs more/better?

   Prompt:

   Mandatory/Marks for completing/submit assignment?

   Design changes **–** shorter, better guidelines on use?

5. How did the PLAs impact your interactivity with others?

   Prompt: Any collaboration/Sharing links with friends via Tinkercad/ Discussed with classmates/More confident to ask questions.

Theme 2: Emotional Engagement with PLAs

6. What did you enjoy most about using the PLAs?

7. How important/valuable did you feel the PLAs were for your learning?

8. Explain how the PLAs impacted on your feelings of preparation in advance of doing the laboratory?

9. Explain how the PLAs impacted your sense of control over your learning?

10. How do you feel the PLAs impacted your engagement levels in the laboratory?

Theme 3: Cognitive Engagement with PLAs

11. In what way did the PLAs help you understand the theory?

    Prompt: Video: Tinkercad:

12. In what way did the PLAs help you understand how to build a circuit?

    Prompt: Video: Tinkercad:

13. How do you feel the PLAs enabled you to gain a deeper understanding of electronics material?

    Prompt: Linking theory to practice, connecting concepts as opposed to surface learning (memorisation, recall)

14. How do you feel the PLAs impacted your feelings of confidence in the laboratory?

15. How do you feel the PLAs impacted your motivation to learn?

Theme 4: PLAs: Benefits, Challenges and Improvements

16. What were the benefits of using the PLAs for your learning?

17. What were the challenges of using the PLAs for your learning?

18. What suggestions do you have to improve the PLAs?

    Prompt: Design of PLAs or structure within module?

19. Have you any other suggestions to improve student engagement?

20. Have you any suggestions to improve the overall laboratory learning experience?

21. Have you any additional comments/points you would like to make that have not already being discussed?

Wrap-up and Thanks.

22. Have you any questions in relation to your contributions? Audio recording, data storage etc.

Session concluded. Audio recording stopped.

Appendix 9: The Focus Group Transcript

Transcript of the Focus Group on the PLAs held on Thursday 21st November 2019.

Mod. Ok, so welcome to the Focus Group for the PLAs. We have 5 participants present and the date is Thursday 21st of November. The participants will introduce themselves and then I will kick-off with the first question.
A. I'm Participant A and I'm from Group A and I'm doing Bachelors in Computer Engineering.
B. Hello, I'm Participant B and I'm in Group A and I'm studying ICT Engineering.
C. Hello, I'm Participant C and I'm in Group A and I'm studying Network Management with Cloud Infrastructure.
D. Hello, I'm Participant D and I'm in Group B and I'm doing a BEng in Computer Engineering.
E. Hello, I'm Participant E and I'm doing a degree in Computer Engineering.
Mod. The first question is, **How did you use the PLAs, so in terms of watching video/ Tinker cad – what was your combination - so a general overview of the 4 weeks of how you used the PLAs?**
D. Well, I suppose the PLAs, kind of on more easier weeks I would only really watch the video because I would understand how to make the circuit from the video, but on some of the harder weeks with the voltage divider I would use the Tinkercad (TK) after the.(watching the video)..to understand a bit better.
E. In my starting week, I had forgotten about it, but before class I did watch the first video. In the weeks that followed however, I did make sure to watch the video and do the TK. And my way of doing it was I would watch the video and then do the TK, but while I was doing TK I would also replay the video side-by-side pausing at given moments just to make sure my understanding was correct.
A. I would watch video at starting of the weeks but then I got rid of it...but like, it was better for me when I used it after because I could understand where to put things in the breadboard (BB) and it got me more relatable to TK.
Mod. So Participant A, are you saying you didn't use TK...you only watched the video.

AYes

B. Yeah, I would watch the video in full and then I'd open up TK and start to put the circuit together. If I needed anything else to help my understanding I would re-watch parts of the video to make sure everything was going alright and just check measurements.

Mod. Ok.

C. I watched all the videos and TK for the 1st couple. After I didn't find it necessary to do the TK, so I just watched the videos.

Mod. Ok, so you thought the videos themselves were enough, ok, that's perfect...

How do you feel the PLAs impacted the time and effort you spent learning?

C. I thought they were good, so like a faster speed, get through them quickly, and follow along and good way to get information efficiently.

D. Is this like related to class, like timewise?

Mod. Yes, so did it encourage you to do more study outside of class, would you have done preparation for the lab if you didn't have the PLAs, that kind of thing...

D. Without the PLAs I would have went into ever class blind, wouldn't have known what to do because I am not going to go out and research it like...just the handiness of having the information given to you every week, I felt that in class every week I flew through the circuits because with TK I knew what to do

E. I found it very similar; having the PLA given to you helped you doing study prior to class. If you wanted to do the study yourself you would have to go through and find the correct PowerPoint and decide to try and build a circuit with TK but with the PLAs it really helps you to focus on what you need to do. It was very useful.

A. Yeah, I think it's good as well, it lets you know what you are doing instead of going and not knowing what to do, not being clueless.

B. Yeah, they were very specific to what we were going to be doing in that particular lab. As the other have said, rather than having to research things yourself, you could look into something you don't need to do, if it's there its grand, you can run through it and you feel prepared then when you go into class. You can work through the lab and get it done quicker and understand it a lot better.

Mod**. How long would it normally take to do the PLAs?**

D. I think 20 mins, 10mins for video and 10 min for TK. Sure once you've done it, then you know it. I suppose for you, it means you don't have to spend half an hour doing it in front of us because we have it done already.
Mod. [Nods of agreements from others] How did the PLAs impact your interactivity with others? Did you share any of your ccts on TK.?

E. Although I never shared ccts, if other students were doing TK in Open Access we would compare our ccts side-by-side, in most cases we had no faults but I can imagine if one person on their TK was getting incorrect measurements we could figure out together what was going wrong. And in class as well when I went in feeling very confident with what I was doing and just knowing the cct well I was giving that knowledge to other students who I was working with.

D. I didn't share anything with anyone but then, in class because we were working in pairs because there was not enough BB, I was kind of watching people and if they were making mistakes I was helping them out because I knew how to do it.
B. Yeah likewise, I didn't share anything (in TK) but in the lab because you knew what you were doing, if I had my cct built and measured and someone else was struggling, because I understood I could turn around and help them maybe.
C. People learn better from their peers so works well.
A. I learn better when I do it physically, so I learned more when I do it by hand.
Mod. So, you felt you learned better... 7.55
A. Yeah doing it rather than watching it...

Mod. So, what did you enjoy most about using the PLAs...if anything...?
B. TK is a great app. You can seeing going forward, still in simple enough ccts at the minute, but I assume as it progresses ccts will get more complicated and if you can run test cct in TK before going to the lab, rather than being in the lab and trying to put something together and it's just not working, I can see that TK is a great app going forward. Likewise, the videos, just to go over and give a brief synopsis of what's going to be happening in the lab and to go back over what was done in lectures is very good.
E. I would definitely say the same. With TK I found the interactablility of it was actually fun to drag the different components and set-up in the correct way and then,

going into class with the knowledge, I found that to be very likable, to be going in knowing exactly what you were going to be doing, to be fully confident.

D. I suppose even from the PLAs in Interface Electronics, having a better understanding of the labs and the subject makes the subject a bit easier and from that I have enjoyed the subject a bit more.

Mod. A, C, Anyone else? [No]...ok.... **How important/valuable did you feel the PLAs were for your learning?**

E. I found the PLAs very valuable. Going into class with the additional knowledge, being able to do my ccts correctly, without having to spend 15mins wondering why I'm not getting the right current, I could take measurements correctly, I have the theory and have time to spare to help others in the class.

D. The big thing was the skills exam, just studying for that I used all the pre-labs again, and I did well in the skills lab because of that.

C. Yes, they are a good revision tool.

B. Very good the way TK saves your previous circuits so it wasn't a case of having to go back in and re-build the cct, I could go back and open previous cct, so studying for the test it was very good, I was very familiar with it and knew what was going on.

A. I was new to all the circuits and everything, so when I used TK it showed me the basics that you need to know, got me basic knowledge of circuits, so it helped me like that.

Mod. Explain how the PLAs impacted on your feelings of preparation in advance of doing the laboratory?

C. Made me much more confident going in.

B. Yeah, likewise, feel more prepared for the lab, know what going to be going on, not going to be a shock going in there looking around not knowing what to do.

A. Felt very comfortable using the BB, not like I'm going to blow things up.

D. Yeah, that's the main thing, going into the lab and I didn't need you holding my hand every time.

E. Yeah, going in, just going over the quick brief and you know what components you need – I need 3 Resistors, I need 1 POT, 5 wires, go back down and all straight in (to BB), just more efficient. You never really doubt yourself as much.

Mod. Ok... so there might be some overlap, but explain **how the PLAs impacted your sense of control over your learning?** [12.09]

C. If you put time into watching the video and TK then you would have an advantage.
B. Video, less than 10mins, Tk 10mins, so less than 20mins and your prepared and it could save you half-hour to an hour just sitting in the lab of trying to figure things out. Very beneficial in that way.
A. You can re-watch the videos so if you don't understand it on the first run, you can do it again and again until you get a better view.
E. Yeah, with the videos and your TK ccts being saved on-line and easily accessible, when I build my ccts and I name them with a convention that if you want to do revision…. you know exactly where to go…you don't need to dig through a pile of note or power points, In terms of control over your learning, it means all the information you need is very easily findable, you know where to go for the exact information you need.
D. I suppose it's like being in class again coming up to Christmas exams, there is a lot of theory and maths and you run through that over and over again so it's a handy way of memorizing formulas.
Mod. How do you feel the PLAs impacted your engagement levels in the laboratory? 13.58

A. I felt it was better because if I didn't know certain parts, I could talk to people who had done PLAs, [looks to B], and he could help me out because he had done the PLAs already so that was good.

E. In the reverse, I found it was very good because I was helping another student who was struggling a little bit with it, although we were working on the same BB, his knowledge of the theory was about behind so I was explain things to him, pointing out things so like KVL, that was one I was explaining,

D. In terms of engagements, I felt I was fully engaged, I didn't need help doing any of the circuits, and if neighbours didn't know how to build theirs, they could ask me… was there if they needed help.

Mod. In what way did the PLAs help you understand the theory? Video/TK or lecture most useful? Same question, on how the PLAs helped you understand how to build circuits? Video/TK or practical?

B. Videos helped, it's easy to see if the formulas are written down, its one things to try and learn them off but then when you physically see the circuits I the video and you can sub the numbers in, you know how it worked out and it makes way more sense that way to see it that way, to see it physically worked out rather than seeing formulas there and trying to work them out yourself, and its explained throughout so if you don't understand you can go back and watch a part… I found that very helpful.

E. I'd certainly say that the videos contributed more towards the learning of the theory, but I also found when using TK, when measuring voltage and current, it helps you to understand say voltage drop change, if you change a resistor for stronger one you can re-measure how that changes and that contributes further to the understanding of the theory.

D. Yeah, definitely, the videos are the big one for theory because, you run through the theory in the video and then you link it to TK – so this is how I got my theory, this is how I got in on the circuit, the fact you are linking the theory to the circuit makes it easier to understand, you're not just writing up numbers and going… understand that.. you know.

Mod…… [Low volume] So PLAs then, **how did they help you understand how to build a circuit? 17.35**

E. For the circuit, it was very useful doing it in TK…just laying everything out..then when you walk into the classroom you go, wire goes here, resistor goes here, I measure here, and it makes it simplified.

Mod. So, for you A, who may not have done TK and mainly watched the videos, how did you get on building the circuit. Did you still find the PLAs helpful?

Mainly focus on TK.

C. At the start I think TK was very useful, helps understand how to measure current and how to measure voltage, where you need to break the circuit to measure certain things but then as you progress I think the video was just enough because it is quite repetitive putting the components onto the breadboard in TK.

Mod. So, you think TK was good to get the basics of how BB works

C. Yes good for basic measurements.

Mod. So, when building circuits in the lab using the BB it can be a little flaky/difficult to get things to work, **do you think having done the PLAs you have more confidence to debug your circuits more.**

D. Watching videos and doing TK, if something is not working with your circuit you know your circuit is rights, it's just because you have not put something in properly it's not because circuit is not built correctly, something is just not pushed in far enough, just something silly like that, it not because circuit is wrong is the main thing.

C. Yes TK, doesn't allow for loose connections so cements what you have learned is right... not your fault [if doing it right, cct will work]

D. Yes, yes, TK does not have broken links.

Mod. Ok, **how do you feel the PLAs enabled you to gain a deeper understanding of electronics material?** So obviously TK is good for step-by-step instructions but in terms of the deeper understanding of the terms V, I, R, can you genuinely say you have a deep understanding (more than memorization) of the material?

C. It's good to be taught through multiple different mediums, you taught us in class, come around to us, then on top the videos are just another platform another way to try and understand.

E. I just found with TK, as I mentioned before, TK can be bit repetitive putting same components back in, over and over again but still found that by doing it over and over again you were really reinforcing your understanding and you know when put resistor in the effect it is having on the circuit.

D. The videos reinforce the theory you teach in class, calculating current, KVL, KCL, Ohms Law and all that, you go through all that in the videos so good to run through a second time or if indirectly we still getting it.

Mod. Anyone else any thoughts…Ok, **how do you feel the PLAs impacted your feelings of confidence in the laboratory?**

B. Greatly, feel prepared going into the lab, when you make the circuit perfectly, you're like, this is great, So, you feel like you are learning quicker and taking things in a lot better.

E. Definitely, the very same. And also, when, say you have a test coming up and you're doing the PLAs you're not getting stressed and worried, you feel like yeah, I'm definitely going to be able to do that.

D. I find if you're going into something blind [the lab], you will barely scrape through it without understanding it at all, you're not going to remember it the next day. If you have done the PLAs, you will know what you have done, and you can do it again if someone asks you.

That was a big thing in the skills exam, since I had done the PLAs, knew what to do in skills exam.

Mod. **How do you feel the PLAs impacted your motivation to learn?**

A. For me, it motivated a lot, I was learning a lot using TK than videos, I was experimenting a lot in TK than video, and it motivated me a lot to build circuits…Resistors and wires in the right way

Mod. So, were you doing your own circuits and experimentation…?

A. I was building circuits, but then I was experimenting, what if I put this Resistor in, what if I put this capacitor in, what are the effects, what's the result?

D. The big thing is, it stopped me getting fed-up with the subject; the fact that the PLAs made it a little less hard is a big thing. I suppose with other subjects this kind of stuff is not in it at all and if you don't understand it your fecked.

C. Aren't we supposed to be doing a certain amount of work outside of class on our own….

Watching the video and TK is much easier and more enjoyable than reading notes…

24.06

B. Its having a set thing, if you're told to go off and do an hour's study you're kind of looking there for an hour and what am I supposed to be going over, whereas, if you have a set 20mins and you do this 20mins you will be prepared for your next lab so I think that ways better. Rather than going off and getting lost by yourself if you know exactly what you have to run over, you're going to reinforce what you need to know. I found that very helpful.

E. I just found being able to go into class feeling so confident about your ability and your understanding. Also, it gives a very positive mood, you go into class and you get everything done, you feel good about it and it encourages you to continue doing the PLAs and to continue learning.

C. The routine is good for helping you structure when you should be studying.

D. Knowing exactly what you need to study ever week is a lot easier than flicking through pages guessing what you need to know.

Mod. **What were the benefits of using the PLAs for your learning?**

D. Benefits for the skills exam were a bit benefit of the PLAs for me.

B. Just being prepared for labs.

E. Greater understanding of the topics.

A. Not using the wrong Resistors, wires, for the circuit.

Mod. Anyone anything different to add? 26.

C. Gave me a reason to go to class, because I knew what I was doing so I felt I was going to benefit from class…not sure how to say

D. Yeah, so you knew you weren't going to be an eejit in class, as you said, and you didn't say what the point of going is in.

C. Yeah, exactly. I felt some people would have been like that.

D. Or can't be [bothered] as well…

Mod. **What were the challenges of using the PLAs for your learning**? We had lots of positive so….26.34

C. Remembering to do them. If it was a whole semester thing it would become a habit but since only for 4 weeks, it was hard to get into swing of it.

E. As I mentioned before, in the very 1st week I forgot to do and only had time to do the video. After that, I made sure to remember and I did them every week.

Mod. I sent reminder on the Monday, think I forgot one week, and was that helpful?

B. Yes.

Mod. So, it was a challenge to build into plan. Anything else?

D. Building circuits on TK is slightly repetitive after a while. I think if you had given us the TK already made and if you wanted to go through you could but if wanted to go through it you could but if you wanted to see it built and just see how it worked, you could do that as well.

Mod. **What suggestions do you have to improve the PLAs?**

E. I found while doing the video and TK, I also happened to be doing revision using the test quiz and one question was related to KVL which was related to the circuit in the PLA we were doing at the time, from doing those additional questions as well I found when I went into class for that lab I was much, much faster and had an even better understanding of the theory than just doing the PLAs …doing these additional question on top wasn't just having this here and this here and this is your result, these questions were giving me different numbers and I had to work it out. I went through, did a question, got it correct, and that just really helped to reinforce on top. So perhaps, along with TK, 1 or 2 questions that change up the numbers could provide great benefit.

Mod. So, you are suggesting linking Moodle quiz to video and TK.

E. Yes, so after you do the video and TK have a quick quiz to check your understanding, if you do the questions with the PLAs then you know 100% that your understanding is correct.

Mod. Anybody else any suggestions?...........In terms of the design of PLAs, length of videos, quality of the videos, structure within the module – would there be an argument for doing the TK circuits in class time?

D. Even with PLAs, as handy as you made them some people are still not going to be bothered to do that much, you are still getting them to do them in some way and be prepared. Even if they are not [bothered] to do them at home, I know that is more on students than you but having options to do it [TK] in class could be a good idea.

E. Even though the PLAs are optional and not required to do them, some students even if required would still not do some of them, get a bit lazy so, if had the option to go back over in class, if you missed it or forgot to do it you could quickly do it before getting on to the practical, It might be useful.

Mod. Anybody else?

D. I know there is only so much time for Interface Electronics every week but there are definitely people in the class who would benefit from it if you made them to do.

Mod. But at the expense of what. We have 2 hr practical, so would you be prepared to…?

D. I suppose, the circuits never take 2 hrs to do, if you spent half hour …

E. Only time it takes 2 hrs if you went in there not knowing what you were doing which the PLAs would prevent…

Mod. **Have you any other suggestions to improve student engagement?** Not necessarily just PLAs but…in general…. PLAs at moment you are encouraged to do them, not assessed, not mandatory…….

D. IN class, I know with LDR say its use but bring the circuits into more real world uses makes it more interesting to students. I feel if they could see what the circuits is used for rather than just a circuit. For example, LDR used for light sensor but the lab before I didn’t really know what voltage divider circuit was for, just knew how it worked.

Mod. Good point. Anybody else?

C. Can we comment on the physical lab?

Mod. **Yes, question there on improving the overall lab learning experience.**

C. It can be very hard to see the board at times. I suppose the PLAs do help because you don’t need to see the board as much [laughter.].

Mod. Yes, I know.

C. I know it not your fault.

D. The class is just a bit awkward; the second row is just at the right height that I can’t see the board.

B. The layout of the room is just bad but that nothing that’s impacting anything else. I suppose all the equipment that’s in there is needed so it’s not as if you can strip back.

D. shelves a bit lower….

Mod. So, the fact the PLAs are not mandatory do you think it would be better if they were. I know ye are all very positive and have engaged but do you think if you were getting marks, as you suggested E, for doing a quiz at the end of PLAs.

E. Marks? Mod. Yes, getting marks towards your final grade

E. I think that would boost some people to do it more, they would want the marks to make sure they passed, whether that’s a student who’s trying to get a high grade or a student who behind and wants to make sure they get through. Some will look at and say that only a tiny percent I don’t have to do that. It could encourage more people to do it giving it a mark.

D. I suppose if you gave the PLAS any marks at all people would do them, even I can see, you know the people who have not done the PLAs they are losing marks in class. If you gave marks that would help them to pass the class and maybe they would do better overall…

B. The PLAs are so beneficial, you know what you are going to be doing, I know they are voluntary at the minute and it up to yourself to motivate yourself to do them but if you made it mandatory people might actually look at it and eventually, they would be like this is handy, so even if they looked at it an hour before they went in, you're still going to be having some grasp of what you're supposed to be doing. So, it there was some sort of marks or showing this is how many people have done it,

E. I think on the reverse side, a possible negative effect if they are made mandatory, like we have established here that everyone is doing them and they are completely optional, if they are made mandatory you will more than likely continue doing them but you might have one bad week where you have a lot of work to catch up on and you may start to look at the PLAS more negatively, oh I have to go and do these PLAS when I want to be working on say, a report for another subject so that could be a possible downside if they were made mandatory., it could alter people perception of them, rather than looking as something that can help you but more like work, work, work…

D. The PLAs would just put more work on you if they were mandatory whereas …...?? 36.53

Mod. I am just going to go back to one point, before the end. You spoke about possibly doing TK as part of the lab. The way the lab is structured now is you come in, I recap on theory and do a demo which could take half an hour. Do you think that time would be better spend if people were watching a video or had access to PCs and were doing circuit TK? So, trade this time….

B. I don't think you can take that aspect out of it. If you had a row of computers and anyone who didn't do the pre-labs could just go sit a t a computer half an hour and do nothing. Whereas if you are talking, and engaging they are going to listen. If they are not doing the pre-labs beforehand and they are given a half hour they might not do it anyway.

A. They might not even come in for that 30mins, they would think they have to waste 30mins and they would not come for 30mins and then come in the actual practical lab.

B. Maybe if you asked at the beginning of a lab, who had done the pre-labs. I know it might get messy but if you were to split the lab, so anyone who had done the pre-labs could start up and get going, rather than them sitting there for half an hour going back over the same stuff they already know they can start their work and get going. So maybe split the lab with back and front. People up the front who had not done the PLAs would have to go over their notes or watch you for that half hour to explain what's going on.

E. I definitely think that would be a good idea because, it wasn't in this subject but into another subject where there was a practical and I knew what all the theory was and what I was going to be doing but …I didn't want to shoot ahead and do the practical because I did not want to be disturbing anyone while you were explaining things, instead I just sat there quietly trying to pass the time, I found I lost 10mins or so just sitting there knowing I could go ahead and work but I didn't want to get in anyone's way.

D. I think a good way to get students to engage in PLAs more is the likes of software and maths, there's one tutor class every week for an hour. If you gave that option to students, they could come for the hour, I'm sure the attendance might be [poor] but there's definitely people who would come in and to it then than have to do it at home, so if there was a separate class for half-hour or an hour that could be great way to get students to engage with it.

E. Like the one we have for Maths, the tutor name.

Mod. Have you any additional comments/points you would like to make that have not already being discussed?

C. You can't replace the lecturer, you still need someone to explain the stuff and have the option to ask questions.

E. Yeah like, where we CiscoNetCAD I was getting the perception of like what's the point of having a lecturer or coming in if all of the stuff is there on-the website and we are being told to go on the website and read this but then as it continued on I saw the lecturer he was going over the information in his own way and I was very engaged in the class, rather than just sitting at a computer and read, click, read click actually having someone standing explain it and if I have a question, rather than having to read over the text I can just ask and have them explain it to me in a way that is much more easier to understand,

Mod. Ok, we are going to wrap-up now, anyone else have anything they want to contribute…. No.

E. Try doing the PLAs for other subjects.

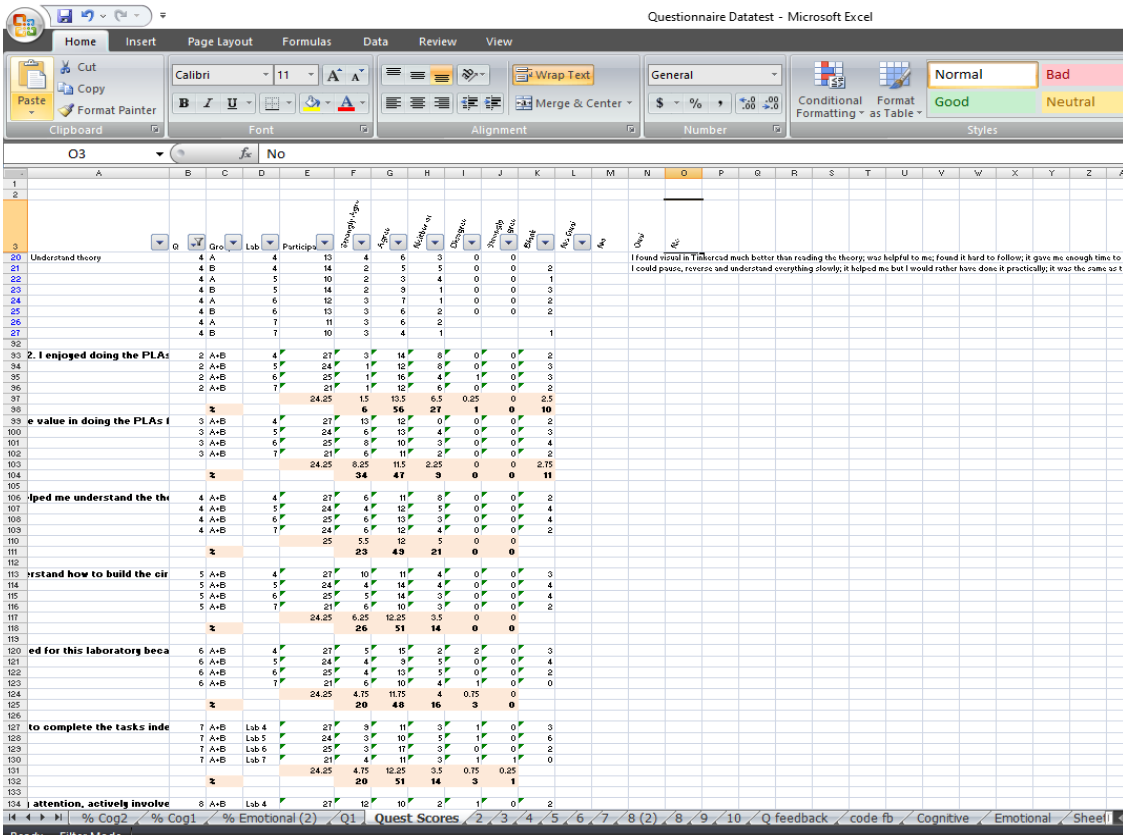
D. Get that sure class going next semester…

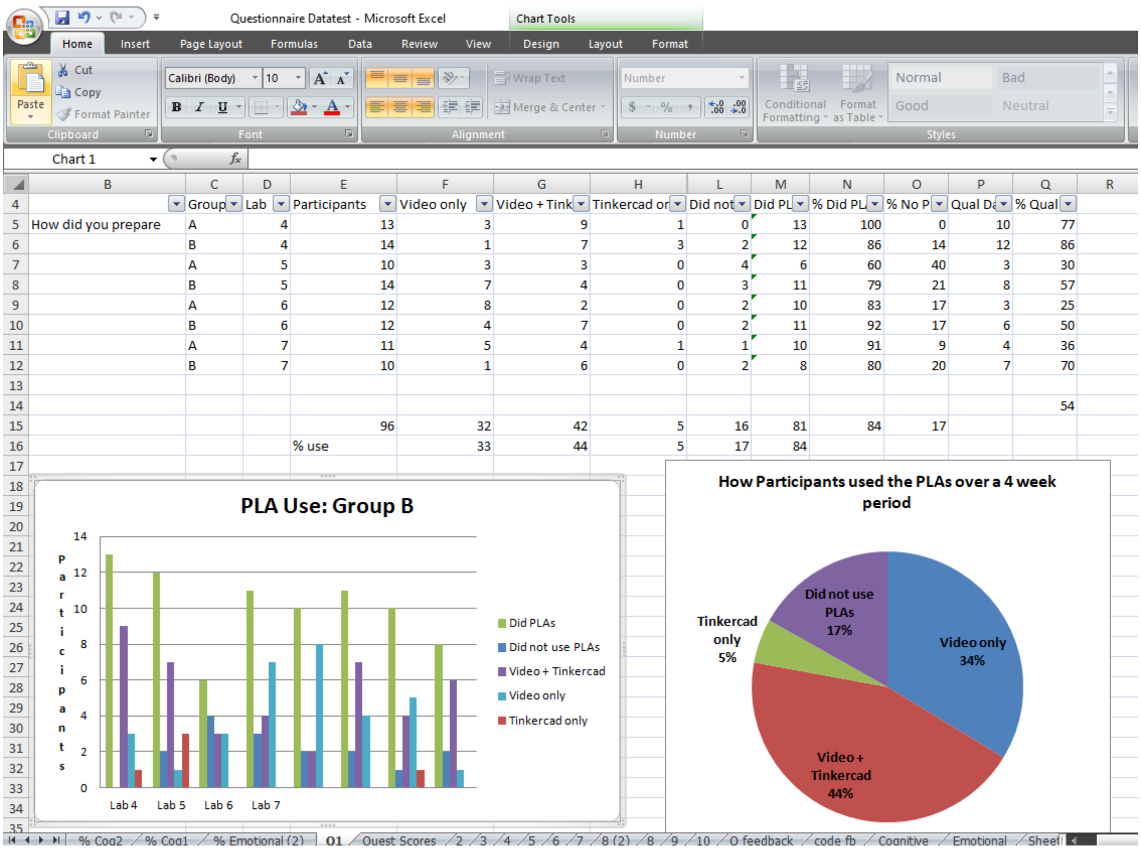
Mod. So, have you any question in relation to the audio recording or data storage, or anything related to this process?

All. No.

Mod. Thanks everyone for the valuable contributions and for really engaging with the process, I really appreciate it. I will now stop the recording.

Appendix 10: Sample of Raw Data from Questionnaires in Excel

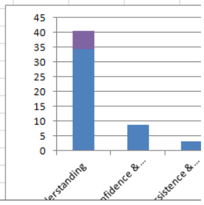




	B	C	D	E	F	G	H	L	M	N	O	P	Q
4		Group	Lab	Participants	Video only	Video + Tink	Tinkercad or	Did not	Did PL	% Did PL	% No P	Qual D	% Qual
5	How did you prepare	A	4	13	3	9	1	0	13	100	0	10	77
6		B	4	14	1	7	3	2	12	86	14	12	86
7		A	5	10	3	3	0	4	6	60	40	3	30
8		B	5	14	7	4	0	3	11	79	21	8	57
9		A	6	12	8	2	0	2	10	83	17	3	25
10		B	6	12	4	7	0	2	11	92	17	6	50
11		A	7	11	5	4	1	1	10	91	9	4	36
12		B	7	10	1	6	0	2	8	80	20	7	70
13													
14													54
15				96	32	42	5	16	81	84	17		
16				% use	33	44	5	17	84				

Appendix 11: Sample of the Frequency Analysis of the Qualitative Data from the Questionnaires using Colour-Coding in Excel

A	B	C	D	E	F	H	I	J	M
					Total comments		215		
Question	Group	Lab					Pos	% of Tot	% of Total
1	A	4	Laptop stopped working, waiting for a replacement		Valuable/Helpful	64	51	24	6
1			I was away for personal reasons		Felt Prepared for Labs	26	24	11	1
1	A	5	Forgot, no laptop over the weekend		Enjoyed PLAs	9	6	3	1
1	B	5	Becasue I wanst home so totally forgot						
1			Totally forgot		Helped Understanding	87	74	34	6
1			Personal reasons		Improved Confidence & M	19	19	9	0
	A	6	Forgot		Improved Persistence & I	10	7	3	0
	B	6	Studying for exam this week so forgot.						
	B	6	Forgot			215	181	84	14
	A	7	I had no time						
	A	7	Didnt have much time due to not feeling well						
	B	7	I forgot about it.						
	B	7	I just forgot to watch the vidoe and Tinkercad						
	B	7	Other. I did equations too.						
			I was also doing a practise quiz which related to this topic.						
			Positive	Negative					
2	A	4	good to have heads up before coming to class;						
2	A	4		was useful but wouldnt describe as enjoyable;					
2	A	4	it helps to see how componetns are put together;						
2	A	4	gives insight into what the class is about;						
2	A	4		it was like homework;					
2	B	4	I enjoyed seeing how everthing worked;						
2	B	4	I didnt look at video but went to TK						
2	B	4		; I didnt enjoy but saw the value;					
2	B	4	TK made the circuits alot easier to understand;						
2	B	4	it wa fun working on TK;						
2	B	4	I thought it was fun to experiment with TK;						



Appendix 12: Excerpt from the Reflective Journal for Lab 4

Group B inputs were written directly after the laboratory session.

Group A inputs were transcribed from an audio recording taken shortly after the laboratory session.

Interface Electronics			**REFLECTIVE JOURNAL** Connect & Discover
Laboratory 4: Resistors in Series and Parallel			
Group/Date	A (14/10/19)	B (15/10/19)	
Date of Reflection	14/10/19	15/10/19	

Practitioner Reflection

The purpose of this reflection is to answer the questions:

- How did the introduction of PLAs impact on teaching?
- What were the observed levels of student engagement?
- What was learned about how the introduction of a flipped classroom strategy, in the form of PLAs, impact student engagement?

Description of laboratory environment	Critique your performance. How did you prepare the students for the laboratory practical? What activities did you do and the students do? Did these change since you introduced the PLAs?

Group A.

First I asked the students how many students had used the PLAs. About 14 out of 18 raised their hands to indicate they had watched the video and they were quite positive about them. I gave everyone 5 mins to fill out the questionnaire and I spent time explaining how to approach by giving details to support their choices.

Next I went through the theory supporting the lab. Students were then guided through doing the calculations underpinning the lab. I walked around and I felt most students had a clear idea of how to do which was very positive. There were a few students who needed guidance on how to approach the calculations.

Next, I used Tinkercad to give demonstrations of how we would build the circuit, what measurements were needed and how this linked to their theoretical calculations just done. I felt this worked better than having 18 students gathered around the Breadboard which make it difficult for them to see what I am doing. I gave students clear guidelines on how to carry out the lab and I then gave them the freedom to work in pairs and proceed independently. Most students are happy to pair up but there were 1 or 2 students who wanted to work independently and they did so.

Group B.

I revised the theory and then got students to do the worked calculations for the lab. I walked around and gave assistance to those who required it. Then I did the solution on the board. Next I used Tinkercad to do a simulation of the practical. I found this worked well as its easier for students to see how to connect the circuit on a breadboard using Tinkercad as