COLLABORATION IN REMOTE ACCESS LABORATORIES

A Thesis submitted by

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Abstract

Collaboration in Remote Access Laboratories (RALs) is becoming increasingly important in both engineering and science education institutions, and with RALs service providers as an enabler to improving accessibility, reducing costs, and improving time-efficiency and student support.

Yet research on the use of collaboration in RALs, in general, is limited. There is a lack of exploratory and empirical studies that provide an in-depth and holistic investigation of the design process and factors that influence the adoption of collaboration in RALs. Therefore, this study makes a significant and original contribution to current theoretical and practice knowledge with regards to pedagogical change in engineering education through the use of technology and remote access laboratories, where social constructivist practices are applied, in particular, engineering students undertaking LAB work in a different mode or approach to the traditional learning environment. This research employed a case study qualitative method with triangulation of data. Data were collected through observation of students working collaboratively in the trial of collaborative learning in RALs using the Voltage Divider Experiment task, and follow-up, in-depth interviews, with inductive analysis and activity recoding. The research explored Kagan's PIES that relate to outcomes of the collaborative approach, Dillenbourg's four elements of collaborative learning and Doolittle's eleven principles of learning experience design as the theoretical bases of the collaborative pedagogical design of the RALs learning experience. While confirming their continued relevance to this context for learning three new principles were shown to be essential to facilitate and enhance contemporary learning in RALs. These included the need to build in the leadership of the collaborative learning experience, ensure task authenticity and participants acquisition of the soft skills, including interpersonal skills and teamwork, and their relevance to the workplace (employability). Additionally, this research highlighted how learning in RALs facilitates formative assessment that feeds forward to better support students' learning where they need to communicate with each other during the LAB work collaborative learning experiences, thus drawing attention to the need for careful academic planning.

The study also addressed the limitations of collaboration in RALs. It investigated the extent to which engineering students accepted collaborative learning in RALs as a workable alternative to traditional in-LAB work. It identified the key factors that are likely to influence the adoption of such pedagogical change, including factors to be considered when planning to adopt collaboration in RALs. This resulted in the development of an instructional framework for collaboration in RALs. It was concluded that collaboration in RALs has the potential to improve LAB learning through the availability of remote access, the facilitation of a sense of reality (comparable to traditional hands-on experience) and the opportunity for group work, and the need for skills that more closely related to those needed in students' future workplaces.

Certification of Thesis

This thesis is entirely the work of Ali Mohamed B. Habibi except where otherwise acknowledged. The work is original and has not previously been submitted for any other award, except where acknowledged.

Principal Supervisor: Professor Shirley O’Neill

Associate Supervisor: Associate Professor Ann Dashwood

Associate Supervisor: Dr Seyum Getenet

Student and supervisors’ signatures of endorsement are held at USQ.

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Table of Contents

List of Figures

List of Tables

Publications Arising from the Thesis

Book chapter:

Habibi, A. M., & Dashwood, A. (2020). Changing the LAB experience in undergraduate engineering: How an online approach can improve formative assessment practices and learning. In C. Dann & S. O'Neill (Eds.), *Technology-enhanced formative assessment practices in higher education* (pp. 215-239). Hershey, PA: IGI Global.

Abbreviations

CSCL	Computer-Supported Collaborative Learning
FA	Formative Assessment
G-code	Geometric code
GPIB	General Purpose Interface Bus
GUI	Graphical User Interface
HREC	Human Research Ethics Committees
HTML	Hypertext Mark-up Language
ICT	Information Communications Technology
LAB	Laboratory
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
MOOC	Massive Open Online Course
MOSFETs	Metal Oxide Semiconductor Field Effect Transistor
PIES	Positive Interdependence, Individual Accountability, Equal Participation, and Simultaneous Interaction
RALs	Remote Access Laboratories
TEFA	Advanced Technology Formative Assessment
URL	Uniform Resource Locator (web address)
USQ	University of Southern Queensland
VI	Virtual Instrumentation
VRLS	Virtual Remote Laboratories
WEB	Website
ZPD	Zone of Proximal Development

Chapter 1 INTRODUCTION

This chapter presents a brief introductory overview of the research topic of the thesis. The chapter is divided into six sections. Section 1.1 presents the purpose of the research and Section 1.2 outlines the research background and introduces the research context. This is then followed by a discussion of the statement of the problem in Section 1.3. and the research questions are outlined in Section 1. 4. Section 1.5 presents the thesis outline, and the last section, Section 1.6, provides a summary of the thesis chapters.

1.1 Research Background

Laboratory work is an essential part of education, particularly in the fields of science and engineering. Remote laboratories are a class of online control systems that provide access to laboratory infrastructure and learning environments through an interface provided on the Internet (Kritpolviman, 2016; Lehlou, Buyurgan, & Chimka, 2009; Touhafi, Braeken, Tahiri, & Zbakh, 2018). In recent years, extended activities have resulted in a number of users being able to access equipment from anywhere at any time to suit their needs with no time constraints (Baltayan, Kreiter, & Pester, 2018; Gomes & Zubía, 2008; Rampazzo, Cervato, & Beghi, 2017; Winzker & Schwandt, 2019).

Remote laboratories eliminate the need for the physical presence of students in the laboratory (LAB) and, thus, can offer a variety of logistical and economic advantages over traditional co-located LABs. They may also supplement traditional laboratories that do not provide remote access, as well as providing new learning opportunities for students. For example, students who are located in different countries can perform experiments together in RALs, thereby providing the opportunity to enhance the participants' intercultural capabilities (Gustavsson et al., 2009; Nedungadi, Ramesh, Pradeep, & Raman, 2018; Soria et al., 2018; Wang et al., 2016; Wang et al., 2017). The Internet has enabled RALs to be conducted at any time in any geographical location. Thus, the approach allows a pedagogical shift to adopt or develop collaborative learning, which can enhance students' skills in the same way as the on-campus experience.

Collaborative learning is generally defined as “a situation in which two or more people learn or attempt to learn something together” (Dillenbourg, 1999, p. 1) and, more precisely, as joint problem-solving. In a collaborative learning environment, students work towards a common outcome, where they depend on and are accountable to each other. Lau (2006), and later Al-Rahmi and Zeki (2017), confirmed that peer collaboration could play a key role in positively developing social interaction and communication skills of students and influencing positively the outcomes of their learning. Moreover, technology-enhanced approaches to laboratory work that involve students in critical, reflective dialogue with their peers through structured collaborative learning experiences have been found to enhance learning outcomes, and provide students with increased satisfaction (Estriegana, Medina-Merodio, & Barchino, 2019). Salmons (2019, p. 6) elaborates further that “[C]constructing knowledge, negotiating meanings, and/or solving problems through the mutual engagement of two or more learners in a coordinated effort, using information and communication technologies (ICTs) for some or all of the interactions”. However, according to Gillet, Ngoc, and Rekik (2005); Kennepohl and Shaw (2010); Lowe, Berry, Murray, and Lindsay (2009); McCusker, Harkin, Wilson, and Callaghan (2013), while the majority of traditional laboratory exercises are group-based—which implies some form of collaboration—the vast majority provide only limited support for this approach. These researchers also point out that while the traditional laboratory may have the potential to provide the opportunity for collaboration, learning benefits may not be achieved as students typically work alone for logistical reasons rather than pedagogical. Shifting to a collaborative approach has been found to lead to increased quality of peer interaction (Visschers-Pleijers, Dolmans, De Leng, Wolfhagen, & Van Der Vleuten, 2006) and, in turn, improved academic performance (Ada, 2009; Chen, 2011; Lee, 2009; Panitz, 1999a; Zhu, 2012), while promoting soft skills development, teamwork, communication skills, interpersonal skills, problem-solving and critical thinking skills (Ada, 2009; Hughes, Bradford, & Likens, 2018; Jerome & Antony, 2018; Johnson & Johnson, 2013; Kabilan, Adlina, & Embi, 2011; Lee, 2009; Panitz, 1999b; Saputra, Joyoatmojo, Wardani, & Sangka, 2019; Wang, Poole, Harris, & Wangemann, 2001), as well as increased student satisfaction with the learning experience (Chen, 2011; Gray & DiLoreto, 2016; Hughes et al., 2018; Zhu, 2012).

This approach has also been found to enhance students' learning of the value of teamwork, and their ability to present their ideas and recommendations in teamwork processes (Ku, Tseng, & Akarasriworn, 2013; McEwan, Ruissen, Eys, Zumbo, & Beauchamp, 2017; Wang et al., 2001). In addition, there has been some empirical indication of the positive effects that the features of collaboration can provide in RALs (Aziz, 2011; Bochicchio, Longo, Zappatore, & Tarantino, 2015; Cubillo et al., 2013; Gravier, Fayolle, Lardon, & O'Connor, 2012; Hanson et al., 2008; Inayat, Amin, Inayat, & Salim, 2013; Jara, Candelas, Torres, Dormido, & Esquembre, 2012; Scager, Boonstra, Peeters, Vulperhorst, & Wiegant, 2016; Tsekeridou, Tiropanis, Christou, & Vakilzadeh, 2008; Weisman, 2010), yet most online LABs have lacked focus on supporting collaborative group work time; and only a few are constructed in such a way to allow involved participants to be collaborative and operate in real-time (Broisin, Venant, & Vidal, 2017b; de la Torre et al., 2013; Gleich et al., 2019). Therefore, it is essential to investigate this line of enquiry in terms of how the online LAB learning experience can be improved to better support authentic, collaborative learning where students engage in critical dialogue as opposed to a traditional monologic experience.

1.2 The Purpose of Research

The purpose of this research was to explore the potential use of Remote Access Laboratories (RALs) in undergraduate engineering courses to provide a more contemporary pedagogical approach to learning as opposed to the physical in-LAB learning experience. The physical in-LAB requires students to be present on campus at designated times. The research recognises the increasing provision of higher education in online learning environments and the challenge for some disciplines such as engineering (electronic engineering in this case) to be able to take full advantage of information communication technologies (ICTs) in the provision of LAB work. To achieve this purpose, an existing theoretical framework, which facilitated collaboration, was applied to develop instructional principles in the context of remote access laboratories (RALs). This framework drew upon Kagan's (1992) PIES an acronym that refers to the outcomes of effective collaborative learning: ***P****ositive interdependence,* ***I****ndividual accountability,* ***E****qual participation, and* ***S****imultaneous interaction* for effective collaborative learning, Dillenbourg's four elements of collaborative learning, and Doolittle's eleven principles of learning experience design. These instructional principles were tested against several learning activities, thus allowing the research to identify enablers and inhibitors of effective collaboration in the given context. The research investigated how to best support students' collaboration in RALs using an online platform. It suggested strategies to transfer existing practical principles from face-to-face mode and apply them in the online environment and, subsequently, formulate a framework in keeping with the facilitation of collaborative learning in the online environment.

1.3 Statement of the Problem

Different types of laboratories (such as hands-on, simulation, and remote) encounter the issue of how to organise the learning experiences so that students can work together effectively. Lowe et al. (2009) and Broisin et al. (2017b) noted that the problem encountered in most remote LABs is that there is minimal support for collaboration when students from different geographic locations are linked together. The practice has mostly involved the maintenance of one-to-one contact between students and the physical equipment. Previous studies such as those of Huang (2015), Nafalski, Nedić, and Machotka (2011), Nedić and Nafalski (2011), and Gleich et al. (2019) confirmed these kinds of obstructions and identified that few remote laboratories offer a collaborative working environment, despite the increasing demand from universities worldwide for the provision to be made available. Ayodele, Kehinde, and Akinwale (2015) claimed that the power of collaboration in learning is the virtual reality of the learning context, which can be created through using social networking platforms (such as Zoom, Cloud, Skype, WhatsApp and Facebook technology); and this approach can combine the strengths of individuals in the learning experience. They argued that the availability of ICTs has established a new trend, where the much-encouraged collaborative approach to learning in keeping with social constructivism can become the norm. Most recently, collaborative learning has been argued as providing opportunities to improve student learning outcomes, particularly in the higher education sector; and specifically for changing the traditional LAB experience in engineering contexts (Eryilmaz, Thoms, & Canelon, 2018; Spikol, Ruffaldi, Dabisias, & Cukurova, 2018). Its potential application in RALs began after a project designed by Gustavsson et al. (2009). By sharing resources and infrastructure between institutions in different countries in spite of resource limitations, it demonstrated that students in these different locations could conduct experiments in collaboration with each other. Through conducting experiments together they were also able to enhance their cross-cultural competence and allow students with disabilities to participate in the online environment. Gahungu and Freeman (2015) also noted remote laboratory can be a way to enhance the intercultural competence of participants from an international perspective. However, further research is required to explore both the efficacy of the collaborative approach for teaching LAB work in engineering in the context of RALs; and engage the views of students towards such pedagogical change.

1.4 Research Questions

Given the focus of this research, it is important to note that the availability of the Internet and virtual learning spaces, such as those afforded in RALs, not only have significance for enhancing teaching and learning, but have the potential to contribute to building a competitive advantage for education providers by enabling the expansion of the provision of courses online. Yet, using collaboration in RALs can also present many challenges—not least of all is ensuring both the quality and effectiveness of the pedagogy involved and students' learning outcomes.

Currently, there is limited research on collaboration in RALs and, consequently, a gap in the research. A review of the main studies into RALs in the field found that the vast majority of RALs provide only limited support for collaboration. Thus, in choosing to address this challenge in the context of engineering education, this study sought to answer the following research questions:

RQ1: To what extent is collaborative learning in remote access laboratories accepted by engineering students as a workable alternative to traditional LAB work?

This question sought to explore collaborative learning in remote access laboratories.

Research question 2 sought to identify how best to introduce collaborative learning in RALs and the issues involved, and a sub-question was developed that focused on the impact of this pedagogical change on practice.

RQ2: What are the actual factors that need to be considered when adopting a collaborative approach to learning in RALs?

Sub-RQ 2.1: What does a shift to a collaborative learning approach in RALs require in practice?

Research question 3 focused on identifying the benefits of the collaborative approach for teaching in RALs.

RQ3: What are the actual significant benefits to students in adopting a collaborative approach to the RALs?

Thus, the research aimed to explore the shift to a collaborative learning approach in RALs and to suggest how to effectively implement it in practice.

Since learning through LAB work is relevant to students from high school to university, this research has broad applicability to enhance the LAB learning experience and, subsequently, students' learning outcomes. In addition, since most education providers are working in contexts where there is limited access to laboratory equipment, these research outcomes provide strong support for the uptake of learning in RALs in its provision of a contemporary framework for future action on pedagogical change in Lab work. Moreover, the research is significant in its focus on collaborative learning in RALs in showing the potential for this form of laboratory experience to enhance the student experience. The study is also vital in highlighting the importance of the design of formative assessment concerning its relationship to the task design to differentiate a feed-forward approach, as opposed to the provision of feedback (Habibi & Dashwood, 2020). In this respect, the research findings add to the field of online collaborative learning, thus paving the way for improving future teaching in online virtual learning environments.

1.5 Thesis Outline

This thesis is organised into seven chapters. This chapter, Chapter 1, has introduced the background of the study and clarified the research problem. It has briefly provided a justification for the research focus, outlining the overall aims of the study and the research questions. It highlighted the significance of the research and its contribution to knowledge. The following chapter, Chapter 2, presents a review of the literature focussing on the collaborative approach to learning environment and what is known about RALs to date, including the types of laboratory experimentation, and differentiates between cooperative and collaborative learning. It also provides a review of LAB learning experience design and the process of formative assessment and key pedagogical considerations. Chapter 2 investigates further the concept of collaboration and collaborative learning applied to LAB work and RALs and the underpinning learning theory in terms of social constructivism; Vygotsky's Zone of Proximal Development (ZPD); and theories of collaborative learning principles and task design. In addition, this chapter presents the theoretical framework, considers the latter theoretical bases, and makes explicit the flow of the research process to contribute to knowledge. Finally, a summary of the chapter is presented.

Chapter 3 explains the learning task activities design that focuses on teaching the use of the Voltage Divider Experiment applicable to electronic and electric engineering courses with respect to how the on-campus mode is transferred to the online mode in the RALs experience. Moreover, the chapter describes how the online RAL experience incorporates the constructivist principles for collaborative learning developed by Doolittle (1995), as well as explaining how Vygotsky's social constructivism theory and the ZPD apply to the task design as a basis for gathering data on the effectiveness of the collaborative approach with the aim of providing a contemporary framework for future action on pedagogical change in LAB work. This chapter also informs on how the researcher designed the task by using LabVIEW software (National Instruments, 2017).

Chapter 4 describes and justifies the research methodology used to gather and analyse data to provide answers to the research questions. Chapter 4 is divided into eight subsections. The first section discusses the research approach; the second section revisits the research questions and shows how they align with the stages of the research and the collected data. The third section presents the case study. and the fourth section explains the methodological framework; with the fifth describing the research process. the sixth section describing the selection of the participants and explains the research design followed by details of the data collection and analysis techniques and data triangulation, as well as the ethical considerations. The seventh section considers how the research addresses issues of validity and reliability and the trustworthiness of the data and is followed by the final section that describes the use of NVivo software analysis.

Chapter 5 presents the results of the study that relate to the identification of the potential factors that influenced students' successful collaboration in their RALs experience. The results of the study are presented consistent with the research questions divided into three sections. Section one reports the RALs' learning task and collaborative experience; with the second section detailing the activity recoding analysis; and the third section reporting the interview results. Chapter 6 presents the discussion of the findings comparing the results of the study in relation to Kagan's PIES and their ability to show evidence of effective collaboration; Dillenbourg's elements of collaborative learning and whether the eleven constructivist Doolittle principles of learning experience design were fulfilled (Doolittle 1995). It also examines the possibility of other considerations, which could contribute to the design of a contemporary framework for future action on pedagogical change in LAB work. Furthermore, this chapter discusses and answers the research questions in relation to the results of the study and the reviewed literature. The final chapter, Chapter 7, presents the conclusions of the research study, taking into account the limitations of the research, and offers recommendations based on implications for practice and future research.

1.6 Summary

This chapter has provided an overview of the research under investigation. It presented the research background followed by the statement of the research problem. It also provided a brief justification for the research in terms of the literature and purpose. The research questions are outlined, along with the research method and how the research contributes to knowledge. In discussing the significance of the research, it explained the scope and outcomes of the study. It concluded with the thesis outline, which provided a brief description of the content of each chapter included in the thesis. The next chapter, Chapter 2, reviews the relevant literature and explores the emerging field and foci on the adoption of collaborative learning in RALs.

Chapter 2 LITERATURE REVIEW

This chapter presents the literature review. To some extent, it reflects the passage of my research journey as I proceeded with the review of the literature where each section's focus opened up questions that were answered by further exploration of the available research readings until a point was reached. The chapter reviews the importance of online learning, specifically applied to the LAB learning experience in undergraduate engineering courses. The literature is considered in relation to the traditional approach to practice in implementing LAB work in on-campus mode learning experiences, as well as developments regarding the opportunity for LAB learning in virtual online spaces, such as in RALs. The review raised issues and questions in relation to how pedagogical change might be addressed in the undergraduate engineering context and how learning experiences through RALs might be best designed and supported. In general, the review focuses on four key areas to fully explore the research problem: (1) the laboratory learning environment; (2) the types of laboratory research experiments and differentiation between laboratory terms and kinds of access, whether remote or local or virtual or real, including clarification of alternatives to traditional pedagogy (e.g. collaborative versus cooperative learning and exploration of their relevance to implementing RALs); (3) consideration of inquiry-based learning compared with cooperative/collaborative learning in Lab-task design in order to understand how to make a connection between collaboration and remote laboratory and learning design; and (4) the existing research and knowledge of underpinning principles relevant to collaborative laboratories and collaboration in RALs.

Based on the literature review analysis and synthesis, the theoretical research framework was developed, and the gaps in the literature identified to justify the present research focus. Similarly, this chapter summarises the results of previous studies and comparative analyses and evaluates the research methodologies employed to provide implications for future research design, such as that of the present thesis. In addition, the literature review provides a justification for the application of principles of learning experience design and selection of theoretical bases to the RALs learning experience to inform the development of a contemporary framework for the future.

2.1 Remote Access Laboratory

Laboratories are widely used in science and engineering education as a conduit between the theory and practice of scientific phenomena. There has been a significant emphasis exhibited on the importance of education laboratories for engineering and science in the literature studies (e.g. Ayodele et al., 2015; Baillie, Jorre De St Jorre, & Hazel, 2017; Feisel & Rosa, 2005; Gustavsson et al., 2009; Huang, 2015; Kennepohl & Shaw, 2010; Lowe et al., 2009; A Nafalski et al., 2011; Nedić & Nafalski, 2011; Quesada Pacheco, 2013). The laboratory is critical in engineering and science education to ensure students gain an understanding of key concepts and processes. Traditionally, laboratory work has been conducted in a hands-on co-located laboratory. This mode has enabled learners the opportunity to apply practical skills and demonstrate their understanding of the concepts of courses taught in the classroom, linking theory to practice. Laboratories help learners to use critical and logical thinking, and consideration of alternative explanations; and learners can also test and discuss results. Laboratories play a crucial role in the teaching of engineering and science courses, and teachers highlight the plentiful benefits in the process of learning from the increased use of laboratory practices. Hofstein and Lunetta (2004) illustrated the benefits to teachers in their study, and the laboratory can help develop manipulation and monitoring skills, and an understanding of scientific concepts. It can also promote positive attitudes and provide opportunities for student success, as well as promoting skills development in collaboration and communication. The above studies describe laboratories as crucial venues for learning, but they have not examined the role of dialogic engagement with students to clarify how learning is taking place and the impact of pedagogical change on the students’ learning experience

Collaboration in remote access laboratories allows students to perform practical experiments remotely in a collaborative way and to engage with other students at the same time (Odeh & Ketaneh, 2013). Much of the research on collaboration draws on social constructivist learning theories on collaborative and cooperative learning, which is rooted in the work of Piaget and Vygotsky (Bada & Olusegun, 2015; Sawyer & Obeid, 2017; Suhendi, 2018). This research will build on the social constructivism theory (Vygotsky, 1962, 1987) that underpins social learning where learning is believed to occur through social interaction as opposed to learning being understood as the transmission of information (Chandler, 2007; Jonassen & Land, 2014). Active engagement among students is seen as enabling meaning-making where participants co-construct new knowledge together utilizing students working in dialogue in pairs or groups, thereby facilitating their learning.

2.2 Types of Laboratory Experimentation

A critical issue observed from the literature is that many researchers identified that the laboratory was generally linked with 'individual' activity and application in terms of traditional laboratory environments, as shown in Figure 2.1. Some authors' definitions of the term are unclear and, in some cases, the term is used with a different meaning (Abdulwahed & Nagy, 2011). For example, some researchers use the term *virtual laboratory* for simulation laboratory, while others differentiate between the two approaches (*virtual laboratory* and *simulation laboratory)*. Also, when referring to remote laboratories, researchers use various terms such as e-labs, web-labs, virtual-labs, online-labs, distributed learning labs, or distributed virtual lab. The hands-on lab is often referred to as a traditional lab, physical lab or local lab. To differentiate between those terms is that the simulation, as seen in Figure 2.1, is a laboratory that allows students to carry out simulation software experience locally or where software is installed on the student's computer. In the virtual lab, simulation software or other applications that operate remotely may be used over the Internet.

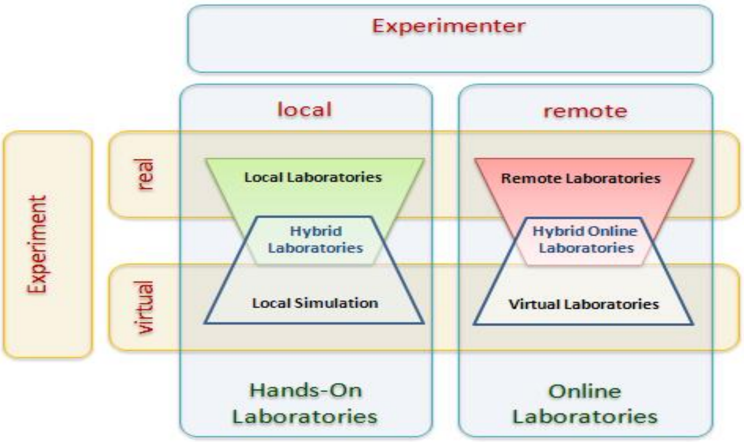


Figure 2.1: Laboratory environments
(Zutin, Auer, Maier, & Niederstätter, 2010, p. 12)

As shown in Figure 2.1, the criteria for how the experimenters (users) interact with the in-Lab experiment may be explained as follows. Students may be local or remote and attend a hands-on the collaborative approach to learning experience of one that is online, respectively, but the introduction of online LAB work presents a change to traditional practice since laboratory courses play a crucial role in the education of science and engineering students. However, pedagogical change occurs slowly. For instance, Labs have changed in nature; and there has been limited discussion about the value of hands-on LAB work which can foster enhanced learning compared with simulation used in the past (Ma & Nickerson, 2006). In addition, RALs added another category in the debate (Ma & Nickerson, 2006). However, it is necessary to review the relevant research literature that has investigated these laboratories in engineering education to gain an understanding of the way they are used and the standards for each type. Also, the review sought to establish the range of use of LAB work and the current state of research in the field in relation to RALs in higher education. Thus, this section focuses on how the LAB depends on experimentation and the experimenters' roles and responsibilities (as shown in Figure 2.1) where the nature of the experiment can be: real or virtual and participants attending might be in a controlled area where they can be local or remote, providing the following possibilities and descriptive terminology:

- The experiment is real and local and is referred to as hands-on LAB.
- The experiment is real and remote and is referred to as a remote LAB.
- The experiment is virtual and local and is referred to as a simulation LAB.

- The experiment is virtual and remote and is referred to as the virtual LAB.

2.2.1 Hands-on laboratory

The method of conducting experiments or building the exercise has traditionally been conducted in laboratories at university campuses. The laboratory includes all the necessary devices and equipment which would be found in the workplace—thus providing the opportunity for students to work individually or as a part of the team with help from a supervisor or tutor (Tuttas & Wagner, 2001).

This laboratory setup requires local on-campus access, and students work directly inside the laboratory. Hands-on labs and practical courses are perceived as being more realistic. They remain essential to understanding the role of theory and mathematics and, conversely, theory into practice in the colleges of the school of engineering curricula. It is also well recognised that qualified professionals play a crucial role in education, particularly in the areas of continuous improvement and the promotion of the development of the field of science and engineering education (Feisel & Peterson, 2002; Hofstein & Lunetta, 2004; Wankat, Felder, Smith, & Oreovicz, 2002). According to Hofstein and Lunetta (2004), the laboratory is the most crucial topic in science and engineering education; and science teachers have strongly argued that a wealth of benefits are achieved in the process of learning from the use of laboratory activities. The traditional structure of the laboratory in education includes the physical presence of a person in charge of the experimental platform. In real-time and with actual equipment, this reflects the label ‘hands-on lab’. In the research literature on these labs, they are sometimes also called proximal labs (Considine, Nafalski & Nedic, 2018; Gadzhanov, Nafalski, & Wibawa, 2017; Lindsay & Good, 2005), since they are seen as providing a sense of realism, which is the essential aspect of hands-on labs. Inclusion of this ‘hands-on’ practice is seen as the essence of effective pedagogy, since using the actual experiences in the educational process is a prime objective in creating a sense of realism. For instance, dealing with the real physical plant: and, therefore, the hands-on lab is seen as essential for students’ learning and development (Abdulwahed & Nagy, 2011).

Thus, there are numerous studies related to the higher education system and the significance of how the learning environment and pedagogy influences students’ knowledge and skills acquisition. These include contrasting the virtual settings with those that adhere to realism (De Kort, Ijsselsteijn, Kooijman, & Schuurmans, 2003; Heise, 2006). In the early work of Kirschner and Meester (1988) and Salas, Bowers, and Rhodenizer (1998) it was argued that this factor of realism achieved better education and training outcomes, and provided a high level of fidelity in terms of skills to be learnt. This argument for 'hands-on' learning is particularly relevant to disciplines such as electrical and mechanical engineering or medicine and health where there is high risk if students graduate without mastery of the relevant essential Lab work. The constructivist learning theory and literature often emphasise the importance of the authenticity of learning environments in terms of being actual or semi-real, to help the learner to build understanding and develop relevant skills in problem-solving (Gallagher, 2004). Hands-on labs are also of importance for students to gain a sense of awareness and skills associated with touch devices. The attainment of such skills has been considered impossible or very difficult to achieve through virtual laboratories or remote labs by many (Abdulwahed & Nagy, 2011; Altalbe, 2018; Grodotzki, Ortelt, & Tekkaya, 2018; Hamza-Lup & Kocadag, 2019). However, of note for the present research is that the utilisation of a collaborative approach that involves student interactions with the laboratory technicians in a RALs context, where the pedagogy involves critical dialogue with student members of the cohort, remains less well known. Moreover, even in general higher education contexts shifting from traditional pedagogy to a more social constructivist philosophy continues to be challenging (McDowell, 2020; Shah, 2019; Taber, 2019). Nevertheless, the engineering laboratory environment offers plenty of opportunities to support students' learning. It can be used for testing and examining theoretical knowledge and its implementation in the laboratory environment, collaboratively. Through real interaction with the actual equipment, it also facilitates learning by allowing students to make errors, which gives them the opportunity to explore the concepts and variables involved. Sidman (2010) pointed out that learning in this way, by trial-and-error, would benefit from task analysis and, unlike trial-and-error learning in the usual sense, the task analysis should be conducted by the learners which, in turn, can inform the analysis and laboratory outcomes (Nedic, Machotka, & Nafalski, 2003). Yet the challenge of how students engage in the Lab tasks and actually learn by trial and error and related discussion has not yet been fully realised (Carmel, Ward, & Cooper, 2017; Dikker et al., 2017; Hernández-de-Menéndez, Guevara, Martínez, Alcántara, & Morales-Menendez, 2019; Rivera-Reyes, Lawanto, & Pate, 2017).

However, there are many elements to consider when teaching through hands-on laboratories. These involve safety issues that may be associated with using dangerous materials in the workplace such that there are risks that the learners may use them incorrectly, which could cause serious injury—especially to novice learners. Students may also cause unintended faults to equipment through misuse, thereby impacting on both the learning situation and the possible heightening of maintenance costs. Moreover, learning knowledge is a complex process that can be beyond the timeframe of a course’s planned hands-on laboratory sessions (e.g., the session time makes it impossible for the student to repeat the experiment because of the limited amount of time available and being confined to the on-campus lab mode). Moreover, hands-on labs are usually taught as one single demonstration due to economic and logistical reasons. As a result, it has been observed that the formation and understanding of concepts require more than one hands-on lab experience, and this has been well established over time (Bagchi, Kaushik, & Kapoor, 2013; Roth, 1994; Wurdinger & Allison, 2017). While laboratory work provides a poor return of knowledge in proportion to the amount of time and effort invested by staff and students, it does not mean that laboratory work is not important since there are more than knowledge goals associated with the lab, but it implies that the time and resources put toward LAB work may not be being used to their greatest potential. Moreover, and as mentioned previously, because of the short period of time available to students in the laboratory, they may not typically have permission or capability to carry out the experiments a second time. In this type of lab, the practice draws upon a more traditional pedagogy, although hands-on, where students observe and work individually to follow instructions in the given time (Kirschner & Meester, 1988). For some time, hands-on labs have continued to be used because they have been viewed as sufficiently educational, as well as meeting economic and logistic needs. However, Bagchi, Kaushik, and Kapoor (2013); Dolan (2016) and Kind (2019) also specify that the formation and understanding of the concepts of a Lab task requires more than one demonstration for students to gain knowledge of pedagogical aspects of their laboratory education. Since the studies considered here, there has not been any exploration of more extended time on task and opportunities for remote learning, or consideration of the importance of Lab dialogic created through interactions among peers.

The practice of the hands-on experience in the laboratory in terms of its practice and time constraints may be considered the weakest strategy for students being able to experience the co-construction of knowledge since the learners have only a short time to interact with the experiments and for absorbing the technical operation of the experiences during the session. The teaching laboratory has been given less attention, especially during the past two decades. Pritchard (2017, p. 141) stated that the "amount of effort people expend to attain a goal depends on the proficiency level required" and there is a consensus that laboratories, in their endeavour to establish instructional outcomes, are weak compared to the time and effort expended in them. These issues and barriers have often been mentioned in the literature (Hofstein & Lunetta, 2004; Kirschner & Meester, 1988; Pritchard, 2017; Roth, 1994). This is further explored in the simulation section where suggestions are offered that may resolve some of these obstacles.

2.2.2 Remote laboratory

The remote laboratory is a one that allows the student to conduct experiments from a distance over the Internet (Herranz et al., 2018; Nedic et al., 2003; Touhafi et al., 2018), and control real hardware and gain real measurements. Remote laboratories have dealt with geographical and/or time difference issues by utilizing the Internet and shared benches at anytime and anywhere, regardless of the geographic region or time differences. The remote laboratory is systems-based and uses real equipment that allows students to set up and perform experiments remotely through the Internet at any time and from any place (Touhafi et al., 2018). It offers real-time experiences, experiments and interaction in a web-based environment where students can control, monitor, and respond to learning about selected scientific experiments (Gröber, Vetter, Eckert, & Jodl, 2007; Tho, Yeung, Wei, Chan, & So, 2017).

The literature often refers to past remote laboratories by using the terms *remote lab* or *lab on the Internet* where the physical platform is controlled remotely (Lipay & Maslov, 2017; Nafalski, Nedić, Teng, & Gadzhanov, 2016; Turchaninov et al., 2019); however, the virtual laboratory term strictly refers to computer simulation in which the remote experiments can be performed from a computer in the classroom or a computer at a remote campus, or elsewhere. Also, remote laboratories can provide advantages for institutes and students to share laboratories, thus providing a possible solution to the inadequacy or shortage of equipment. This online sharing activity could also encompass research centres and industrial organizations. In addition, as a result of the sharing, the university has the potential to save time and money, as well as having the advantage of being able to conduct more experiments in a shorter timeframe. The online (remote) laboratories are platforms that allow remote access to perform experiments and manipulation of the physical equipment through access via the Internet. Examples can be found in the work of Bauchspiess, Guimaraes, and Gosmann (2003) following from Spicer and Stratford (2001). The idea of laboratory application via the Internet for educational purposes can be traced back to the early 1990s, when Aburdene, Mastascusa, and Massengale (1991) put forward a proposal to create an ultimate solution to participation in the laboratory process through the Internet. Early implementation trials took place throughout the United States with remote control robots distributed in four universities and NASA (Aburdene et al., 1991). Year after year, the number of Internet-based learning activities has seen a rapid increase as a result of an initial pedagogical change in Western contexts with online and blended learning being established gradually across the globe and then becoming accepted in the light of its advantages (Sinecen, 2018). Thus, institutes, universities and research centres commenced exploring a change from the traditional Lab experience to the use of RALs, since they have the potential to enable the sharing of resources and deliver a reduction in the economic cost of implementation (Chirikov, Semenova, Maloshonok, Bettinger, & Kizilcec, 2020; Touhafi et al., 2018), as well as enabling the use of new experimental equipment, including artificial intelligence (Eckhoff, Eller, Watkins, & Hall, 2002). Ronchi (2019, p. 90) notes that “remote lab is a completely different experience . . . they enable a completely different experience [from physical ones] . . . users do not need to wait for their turn . . . they can access lab resources whenever they want". However, the resource sharing idea designed to decrease expenses of implementing LAB work began in the decades 1990 to 2000s (Kondraske et al., 1993; Ma & Nickerson, 2006; Spicer & Stratford, 2001). The sharing of remote lab experiences among universities has been found to have benefits for the experiential learning of students (Kondraske et al., 1993). It can also be attractive for higher education since university budgets have limitations, which means the cost of any new experimental equipment regarding laboratory work in undergraduate curricula needs to be carefully considered (Kirschner & Meester, 1988; Stark, Li, Smith, & Chen, 2013). Some researchers have also reported that the use of laboratories via the Internet have been enthusiastically received by students (Callaghan, Harkin, McGinnity, & Maguire, 2008; Ma & Nickerson, 2006). One reason for this is that remote labs may help accommodate different learning styles (Eckhoff et al., 2002). As well, they may suit students because they have been found to encourage communication about the educational curricula, particularly in distance learning in the field of engineering (Eckhoff et al., 2002; Kondraske et al., 1993; Lowe et al., 2009; Salzmann, Gillet, & Huguenin, 2000). The fact that they may connect students from different geographical areas and cultures may also be motivating for students, as well as the potential for flexibility in achieving laboratory outcomes. Remote laboratories provide hands-on experience via remote access to real equipment, which can be advantageous in enhancing students' ability to access real data to promote their critical analysis and reflection (Abdulwahed & Nagy, 2013; Broisin, Venant, & Vidal, 2017a; Heradio, de la Torre, & Dormido, 2016; Ku, Ahfock, & Yusaf, 2011).

However, although advantages have been found in the use of remote laboratories, there are also potential disadvantages. For instance, there is the potential for students not to be exposed to a full range of processes or skills (Aliane, Pastor, & Mariscal, 2010; Bourne, Harris, & Mayadas, 2005). This may relate to the contrast between physical/hands-on Lab works versus a virtual setting, a common criticism which requires further exploratory research, hence, the present study. It is also important to consider other concerns aimed at RALs such as the potential lack of participation of teachers and students, the lack of detailed laboratory instructions and the challenge of providing audio/visual feedback, as well as ensuring the actual quality of the platform (Matijevic & Nedeljkovic, 2018; Srinivasagupta & Joseph, 2003). Although remote access is typically thought to be cost saving it can involve additional costs, which may be low or high based on the nature of the experimental platform. For instance, remote laboratories are more expensive to run than laboratory simulations and can be affected by network performance which, in turn, can impact on reliability (Abdulwahed & Nagy, 2013; Gleich et al., 2019; Stark et al., 2013). While many Lab experiments can be automated to run entirely independently of human input, many others still need to integrate the presence of a supervisor or other expert at the site, and others are impossible to run on the Internet. Experiments that need remote access generally require higher bandwidth, which is not necessarily available in many developing countries and, therefore, limits the applicability where they are most needed (Abdulwahed & Nagy, 2011).

In addition, some literature tends to focus on the effectiveness of a single method in laboratories (Balamuralithara & Woods, 2009), although a variety of different approaches may be considered applicable. For example, learning remotely has been shown to be beneficial because the hands-on lab is seen as less active and more time-consuming (Gleich et al., 2019; Kwon, Chiou, Rauniar, & Sosa, 2007). Yet other researchers perceive the hands-on lab as requiring more effort with regards to the provision of tutoring and evaluation than remote labs (Corter, Nickerson, Esche, & Chassapis, 2004; Matijevic & Nedeljkovic, 2018; Sicker, Lookabaugh, Santos, & Barnes, 2005). Thus, it cannot be assumed that one approach (e.g. hands-on) can be more effective than another, such as RALs; rather there is a need to consider the broader situation and also take into account pedagogical concerns, which may include task design and the roles of participants.

2.2.3 Virtual laboratory or simulation

2.2.3.1 Virtual laboratory

Virtual Laboratories, as shown in Figure 2.2, are defined as laboratories that provide for and allow students to use experimental simulation software operations or other applications remotely over the Internet (Cheng & Chan, 2019; Nedic et al., 2003).

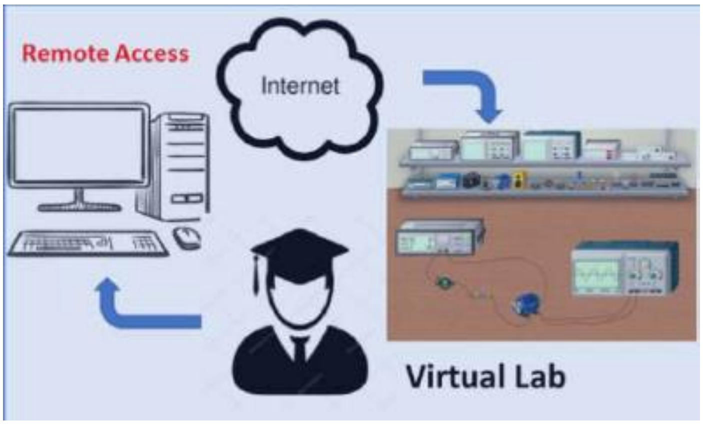


Figure 2.2*:* Virtual laboratory

(Salmerón-Manzano & Manzano-Agugliaro, 2018, p. 2)

2.2.3.2 Simulation laboratory

The simulation laboratory, as shown in Figure 2.3, is defined as a laboratory that provides and allows students to use experimental simulation software locally, which includes it being installed on students' computers/laptops.

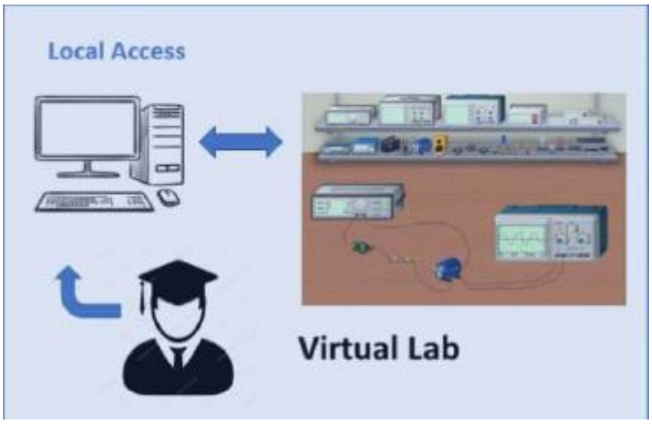


Figure 2.3: Simulation laboratory

(Salmerón-Manzano & Manzano-Agugliaro, 2018, p. 2)

A virtual laboratory or simulation laboratory provides an interactive environment that aims to create a simulation of an experiment (Salmerón-Manzano & Manzano-Agugliaro, 2018). However, there is some difference between the virtual learning experiences compared with a simulated learning experience according to the access method. Specifically, they are referred to as virtual access via online internet laboratory; and simulation can be local access to a computer when the classification depends on the experimenter (as shown in Figure 2.1).

There has been an increase in educators' awareness of the ability of the computer to contribute to pedagogy and learning in higher education (Dann & O'Neill, 2020), especially in simulation experiments in the field of engineering education. Yet this is far from being new, since the Faculty of the Royal Navy, in Greenwich, Britain, was the first to implement it in 1962 with first-year courses for undergraduates. The use of simulation involved a course in Nuclear Energy in the Engineering Department (Abdulwahed & Nagy, 2011). Additionally, the United States was involved at the same time with a parallel experimental approach (Smith, 1992). This led to a surge in the use of experimental simulation, and by the 1970s the concept of the simulation was transferred to computers such that computer simulation became a fundamental part of teaching engineering and science knowledge (Campbell, 1985; Laghari, Suthar, & Cygan, 1990). For example, the Electrical Power Engineering Department at Queen Mary College, UK, used computer simulation software during the early 1970s (Smith, 1976). At the same time simulations were used to teach nuclear engineering students at the Royal Naval College, UK. The simulation was also applied to teaching fluid mechanics and heat transfer (Gosman, Launder, Lockwood, & Reece, 1977). Thus, it can be appreciated that today's LAB work draws upon a strong foundation of practice regarding the recognition of the value of simulation. However, current research and practice rely more upon information communication technology (ICT) that has advanced significantly during the last decades and has fostered new laboratory modes such as described above as virtual (simulated) labs. These provide approximated simulations of the practice of physical experimental rigour. In some situations, these simulation laboratories have become profound alternatives to hands-on laboratories (Gleich et al., 2019; Gonzalez, 2013).

Many researchers have asserted that computer simulation can have a positive impact on students' learning (Adams, 2013; Campbell, 1985; Gleich et al., 2019; Jimoyiannis & Komis, 2001; Kinzel, Charles, & John, 2013; Laghari et al., 1990; Shute & Gawlick-Grendell, 1994; Tjaden & Martin, 1995). However, Gladwin, Margerison, and Walker (1992) and, more recently, Birdsall and Langdon (2018) and; Jamil and Isiaq (2019), have provided examples of best practice involving computer simulation and suggested it was ultimately more acceptable as a tool for the contemporary teacher than a traditional practice. Although it was seen as implying an economic advantage through the decrease in resources, the positive impact of the use of simulation was seen as knowledge building such that upon graduation there was an increase in the students' chance of employment. Thus, it can be argued that there are substantial advantages in using computer simulation since it supports a variety of methods, including being able to build in tests that can be repeated, repetitive displays of knowledge, choice of options, and expected enhancement of students' learning over time. Moreover, it can be designed to allow the learner to reconsider the experiments outside the class, providing an extra opportunity for learning. Thus, reporting and self-testing can be easily incorporated (David, Wyrick, & Hilsen, 2002). Additionally, most relevant to the purposes of the present research, the use of a laboratory simulation program for understanding the design and operation of high-voltage electrical circuits has been shown to be safer compared to hands-on. This is, therefore, more desirable LAB practice since it has the capacity to reduce any associated risks. In addition, the use of simulation helps increase protection/detection in high voltage environments (Laghari et al., 1990). Thus, the availability of virtual labs and the ability to simulate practice makes the Lab learning experience more accessible than ever before as it becomes available anytime and anywhere (David et al., 2002; Ku et al., 2011; Lipay & Maslov, 2017; McAteer et al., 1996). It also allows students to perform problematic experimental laboratory simulations, which may not be the case in hands-on laboratories. Experimentation can be undertaken as soon as a student is ready to do so. The availability of simulation learning activities can be beneficial to both students and tutors since they can stimulate tutors to be more involved with their students in the learning process and use of the concepts and skills at the core of the simulation. Over time it has been concluded that simulation can be an effective model of teaching (Jamil & Isiaq, 2019; Joyce, Weil, & Calhoun, 2009) and a safe and cost-effective for LAB work (Chirikov et al., 2020; Eckhoff et al., 2002; Gonzalez, 2013; McAteer et al., 1996). Additionally, its use in the virtual laboratory can be of benefit in delivering education courses to remote locations (Blanchard, Moron-Garcia, & Bates, 2006; Eckhoff et al., 2002). Some researchers have argued that the use of a virtual lab is able to equip students with equivalent skills to those acquired in a hands-on lab learning experience (Magin & Kanapathipillai, 2000), although Trevelyan (2004) viewed the remote lab as being complementary to the traditional lab learning experience; whereas Hashemian and Pearson (2012) advocate a combined approach to maximise learning.

Although the simulation has barriers compared to hands-on, there are also some additional disadvantages related to the use of computer simulations and virtual labs, which are detailed in the next subsection. Despite the many advantages of computer simulation and virtual labs, there is general agreement between both students and teachers that the simulations cannot and should not always replace hands-on experience (Gordon & McGonigle, 2018; Ma & Nickerson, 2006; McAteer et al., 1996; Ronen & Eliahu, 2000). Even the best-designed program cannot adequately model the real experience and, as a result, that leads to reducing the validity of the realism of the virtual laboratory. As Magin and Kanapathipillai (2000, p. 352) stated: "the arguments against replacement of experimentation arose from findings that students had little appreciation of the accuracy or limitations of computer simulations of engineering systems and devices". Also, the lack of instructor feedback can be another disadvantage of virtual laboratories, since it can lead to a lack of operational skills in terms of how to use the experiment equipment (McAteer et al., 1996). Jeschofnig and Jeschofnig (2011) discuss the mistrust and opposition towards simulation and a non-hands-on approach to LAB work where the practice is argued to be passive. However, they make a crucial distinction between simulation and RALs, the focus of the present research. They note that "modern remote access technology allows scientists time on the Hubble Telescope and to fully operate it from nearly anywhere in the world at any time of their choosing" (p. 53). They additionally note that:

> RALs are often lumped into the computer simulation category... unlike simulations that try to replicate real-world experiences, RALs actually are real-world experiences because they provide access to fully functioning advanced scientific instrumentation that is actually used daily in genuine, real-world science applications and investigations (pp. 53-54).

The benefit of a virtual laboratory is seen as it being able to provide students with skills equivalent to the hands-on lab. Research into students' perceptions of their simulated experience of real field trips showed that they displayed a positive attitude but, in the long run, were opposed. This result was based on a pre or post-instrument to compare their views before and after the learning experiences (Markowitz, Laha, Perone, Pea, & Bailenson, 2018; Witheridge, Ferns, & Scott-Smith, 2019). Nevertheless, from the perspective of safety and the human element in the hands-on lab, the simulation laboratory impacts positively on occupational health and safety since it promotes a safe environment. This particularly applies to students testing hypotheses and the results of investigations into issues encompassing physical platforms that are difficult or impossible to do with your hands sometimes—for example, power plants with high voltage (Hites, Sekerak, & Sanders, 1999; McAteer et al., 1996). To create a remote laboratory, a mix between a hands-on lab and a digital virtual lab has been found to be effective in strengthening educational outcomes (Heise, 2006), which is in keeping with the findings of Hashemian and Pearson (2012). Vlachopoulos and Makri (2017) used this approach of mixing learning experiences involving both a simulation laboratory and a hands-on laboratory in science operations, concluding this may provide students with a better opportunity in relation to developing their thinking skills. However, there was still a need for practical training in physical skills. Important for the present research is that what appears to be absent from the literature is a critical discussion and deeper exploration of the pedagogical approach involved.

2.2.4 Hybrid laboratory

A hybrid Lab is an online lab that combines virtual laboratory technologies and remote laboratories. It also provides real hardware and simulation experiments in software. The laboratory term is defined according to the laboratory users' access (local or remote) and the nature of the experiment (virtual or real). As discussed earlier, the hands-on laboratory is a real laboratory that requires the physical presence of the trainer at a local experimental platform. It requires physical equipment and local access. Magin and Kanapathipillai (2000) also argue that virtual mixing with hands-on labs, such as in hybrid laboratories, may strengthen students’ learning outcomes. It combines remote laboratory and simulation as a package, which results in similar educational outcomes to a hands-on laboratory for the achievement of medium and high-level goals in the laboratory. Other research has also concluded that all modes (hands-on, virtual or remote) provide lifelong learning and the harmonisation of conditions and mixed access to enrich the educational experience for students (Lindsay & Good, 2005). Hofstein and Lunetta (2004) advocate for improved laboratory education standards through the adoption of additional application of ICTs; and Ma and Nickerson (2006) emphasise that all accessible laboratory modes provide fortification capabilities for laboratory education.

Thus, in discussing the crucial features and contrasts between different laboratory modes, including traditional Lab (hands-on), simulation Lab and remote Lab, online also indicates that the RALs can be comparable to the hands-on laboratory (Jeschofnig & Jeschofnig, 2011). Again, it is concluded that there is limited attention paid to pedagogical issues such as how and what communication or collaboration will take place, and related underpinning theory in this regard appears absent; thus the collaborative approach to learning that is facilitated by the technological advances beyond the traditional hands-on Lab is investigated in the present study. The next section discusses the importance of LAB work being underpinned by a theoretical framework and in keeping with the present research, this is applied to collaborative learning in relation to Lab task design.

2.3 Theoretical Framework Collaborative Learning in Lab Task Design

Before explaining the workings of collaboration in remote access laboratory practice, there is a need to consider the theories that contribute to understanding how working as a team has become acceptable in learning—the idea being that students need to work with their peers to achieve enhanced learning outcomes. Spronken-Smith (2007) and Montiel-Overall (2005) pointed out that much of the research on collaboration draws on social constructivist learning theories. These relate to collaborative and cooperative learning, which are rooted in the work of Piaget and Vygotsky; and they also relate to the work of other learning theorists, namely, Dewey (1923) and Bruner (2009). The stance underpinning their theories is that learning is active, and knowledge is constructed through social interaction. Vygotsky (1987) explained that learning happens through active engagement, building on the constructivist realms that underpin social learning. For collaboration in Lab work, it would be expected that students would work together in groups where they would engage in dialogue about the task to create understanding and co-construct new knowledge. Verenikina (2010) argues that if Vygotsky (1987) is correct and students interact in a social or group learning context, the use of technology to connect rather than separate students from one another should lead to higher performance. In addition, one of the Vygotskian classroom principles is that learning, and development is a social, collaborative activity. Hence, collaborative learning is essential in students' construction of new knowledge.

As cited by Roschelle and Teasley (1995, p. 70), collaboration in learning can be defined, as follows: "a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem". Whereas Dillenbourg (1999, p. 1) defined collaborative learning generally as "a situation in which two or more people learn or attempt to gain something together and, more specifically, as joint problem-solving". Dillenbourg (1999) identified four criteria relevant to the learning environment: situation, interactions, processes and effects; whereas Roschelle and Teasley's (1995) definition does not include the situation. However, gaining a shared understanding can be viewed as an effective outcome, and it can also be conceptualised as a process by which peers perform the conceptual change. Shared understanding can be viewed as a condition for conducting effective verbal interactions. Thus, a theory of collaborative learning involves criteria for defining the situation (symmetry, degree of division of labour), the quality of the interactions (e.g. symmetry, negotiability), the processes (grounding, interactive modelling) and effects as per learning outcomes and level of cooperation. The main theories are also based on socio-cognitive and socio-cultural considerations. The second element, 'interactions', relates to socio-cultural theory, and the third element, the process of collaboration, is linked to socio-cognitive conflict theory, wherein this case, the learning task would be sufficiently challenging to the learners to cause them to engage deeply (O'Neill, 2017).

In contrast, the remaining core element of collaboration, which is related to the outcomes of the collaborative learning experiences and processes, are not necessarily linked to a specific theory (Almajed, Skinner, Peterson, & Winning, 2016). However, while the key to understanding collaborative learning is argued to be the accumulative effect of the relations between the four items, the outcomes can also be related to the opportunity for students to be intrinsically motivated, self-sustaining and resilient in their learning, such that they experience ‘flow’ (O'Neill, 2017). Csikszentmihalyi's (1997, 2008) theory of flow refers to the learner experiencing a feeling of self-efficacy and accomplishment, where learning becomes generative (Giroux, 1988).

At first glance, the collaborative learning situation according to the task design generates interactive patterns: these may trigger cognitive mechanisms that in turn exert cognitive effects, thus impacting reflection and critical thinking about the learning. However, it should not be misconstrued as linear causality as that would be over simplification. Most relations are reciprocal (Dillenbourg, 1999) and the interactive processes would be expected to allow students to co-construct their new knowledge through a variety of opportunities for discussion and consensus, where they are able to self-generate their learning. Thus, the design of the Lab task is vital to this learning approach.

In keeping with this view, Vygotsky’s (1987) focus on the value of social collaboration also illuminates how effective learning impacts positively on the individual’s cognitive processes, as opposed to being merely stimulated by them (Dillenbourg, Baker, Blaye, & O'Malley, 1995). Similar to the views of Piaget, Vygotsky emphasised the importance of mixed groups of collaborators (Lai, 2011) since they would be expected to help create a more stimulating interactive learning situation. Vygotsky’s concept of the zone of proximal development (ZPD), as shown in Figure 2.4 helps explain the importance of the task design in being able to be sufficiently challenging, but not too challenging, to engage the learners at their starting knowledge or developmental level. In this figure (Figure 2.4), the distance between the actual developmental level as determined by independent problem solving, and the level of potential development is established through problem-solving under the guidance or in collaboration with more capable peers (Vygotsky, 1987).

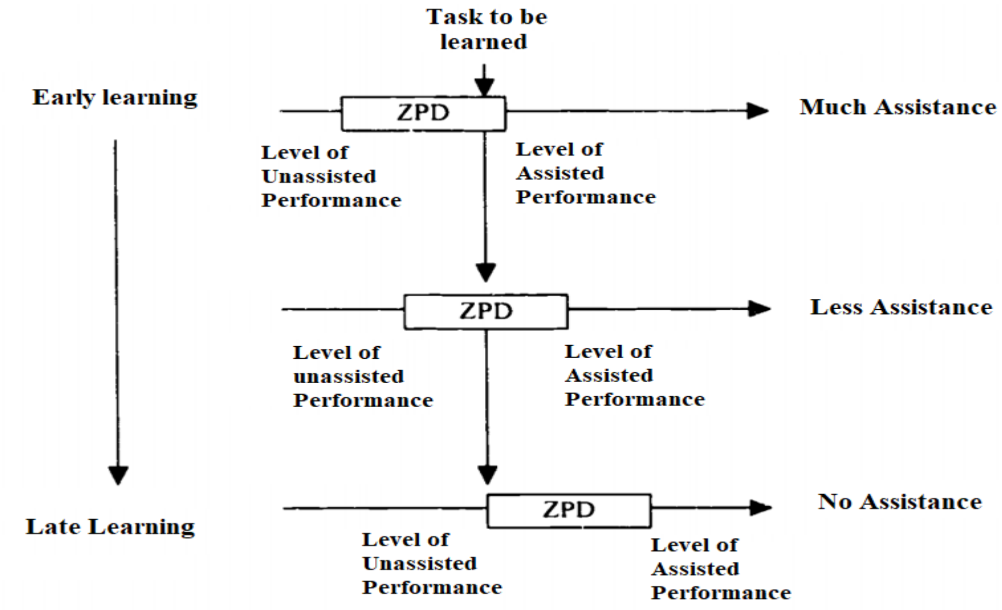


Figure 2.4: Zone of proximal development (Doolittle, 1995, p. 4)

Contrastingly, current Piagetian studies typically pair students from different developmental stages to facilitate cognitive conflict to promote learning. Research in the Vygotskian tradition usually links students with others to facilitate their collaboration. In the social constructivist view, collaborative learning ideally occurs within the zone of proximal development (Lai, 2011). Collaborative learning occurs especially when students need help from each other, which means that the social constructivist approach (ZPD) in Vygotskian theory (Vygotsky, 1987) applies well with collaborative learning. This theory supports the pedagogical paradigm shift that is required to move Lab pedagogy away from the traditional hands-on only LAB work mode to the collaborative learning approach inherent in social constructivism. This provides a strong theoretical underpinning to support the use of collaboration for which Rupp’s (2015) research framework is applicable to remote access laboratories as an aid to students’ development.

Collaborative learning occurs when small groups of students assist each other in the learning process (Klemm, 1994; Laal & Laal, 2012; Le, Janssen, & Wubbels, 2018). It is not necessarily having students talk to each other, either face-to-face or in a computer conference while they perform their individual assignments. Neither is it having students complete a task individually and then have those who have finished first help those who have not yet finished (Klemm, 1994). It is also not having some students do all the work, while others' names are appearing as equal participants are a typical problem associated with group work (Burdett, 2003). Instead, collaborative learning can occur peer-to-peer or in larger groups. Interactive learning, or peer instruction, is also a type of collaborative learning that involves students working in pairs or small groups to discuss concepts and find solutions to problems. Vygotsky recognises that "learning always occurs in a social context and cannot be separated from it" (Salkind, 2004, p. 279). Consequently, collaboration needs to involve instructional strategies that promote the distribution of expert knowledge, where students collaboratively work together to conduct research or experiments, practise using specialised equipment or software and then share their results, and perform or produce a final project, which helps to create a collaborative community of learners.

Teaching in a meaningful context and negotiation among the group to evaluate information to provide enhanced outcomes also reflects the theory of Vygotsky for implementing collaborative learning. The content of social constructivism includes the social environment of the students that directly influence them, including teachers, friends and all the individuals who deal with them through the various learning experiences (Montiel-Overall, 2005). The theory that comes from constructivism also emphasises that students' peers have an important role in participants' individual knowledge building through their interactions. Part of the learning experience includes cognitive conflict and, ultimately, individual growth and social development within the learning and discipline context. This theory emphasises fruitful exchanges of ideas between individuals and progress made through social interactions. Subsequently, the process helps interaction on the cognitive structure of individual growth and continuous development (Fernyhough, 2008). However, there remains a need to research LAB work modes that rely on collaborative learning to explore the pedagogical approach in practice in keeping with these learning theories.

In the past, the shared or situated cognition approach has been informed by researchers across disciplines such as sociology, anthropology and even computer science. It has emphasised the social structures in which interactions occur (Dillenbourg et al., 1995), thus considering the environment as central to the cognitive processes associated with collaboration. As a result, it explores cooperation based on social structures. In this way, knowledge is conceptualised as not something passed on from one person to person but, instead, co-constructed through interaction between collaborators (Lai, 2011). This approach confirms that all group behaviour is more than just the sum of the individual parts. In other words, the interaction within groups will develop in ways that cannot necessarily be predicted based on contributions from group members of the group. This suggests that the latter vision displays more than individual members; thus, the unit of analysis will produce a different point of qualitative conclusions about collaboration (Dillenbourg et al., 1995).

The collaborative approach is used in the present study because, as noted earlier, there is a need for further research on the nature of pedagogy that is applicable in modern LAB work, which may include multiple modes but RALs in this case. It has been established that learning and pedagogical theory supports a collaborative approach where participants work together on the synchronised task rather than in parallel on separate portions of the task. The next section explores in greater detail the concepts of ‘collaboration’ and ‘cooperation’, which Joyce, Weil and Calhoun (2009) consider as models of teaching; however, for this study, a clear distinction is made.

2.3.1 Collaboration and cooperation

The debate about collaboration versus cooperation is complex because common usage tends to treat the two concepts as the same, often using them interchangeably. However, collaborative learning can be distinguished from cooperative learning through the division of work, with each person responsible for some part of the solution to the problem. Collaboration involves the participants working together on the same task, rather than in parallel on separate portions of the task (Lai, 2011). On the other hand, although cooperation is related to social constructivist epistemology, with the goal of accelerating students into the immediate community of learning and the broader world of the target language and culture, it infers less emphasis on interactive talk as cooperation can be observed in different ways. Hence, collaboration differs from cooperation: “Collaboration is distinguished from cooperation in that cooperative learning is considered more structured in its form, more prescriptive to teachers about the teaching technique providing more directives to students concerning how to work together in groups, and is more targeted” (Oxford, 1997, p. 443). Roschelle and Teasley (1995) offer a more detailed explanation, suggesting that cooperative work is accomplished by the divisions in the laboratory or among participants, and is an activity where each person is responsible for a portion of the problem-solving. In contrast, collaboration involves the mutual engagement of participants in a coordinated effort to solve the problem together. The difference between collaboration and cooperation is explained further in the following quotation:

> Collaboration is a philosophy of interaction and personal lifestyle where individuals are responsible for their actions, including learning and respect the abilities and contributions of their peers. In the collaborative model, groups assume almost total responsibility, whereas cooperation is a structure of interaction designed to facilitate the accomplishment of a specific end product or goal through people working together in groups in the cooperative model the teacher maintains complete control (Panitz, 1999b, pp. 3-4).

Dillenbourg (1999, p. 1) defined collaborative learning generally “as a situation in which two or more people learn or attempt to learn something together and, more specifically, as joint problem-solving”. Roschelle and Teasley (1995, p. 70) defined it explicitly as “mutual engagement of participants in a coordinated effort to solve a problem together”.

Based on these discussions, it can be appreciated that collaboration differs from cooperation in meaning on issues of cognition and distribution of work, as well as interaction. Besides, cooperation in the field in determining the distribution of work does not avoid the ambiguity of some spontaneous division of labour, although this may well happen with collaboration (Dillenbourg et al., 1995). Nevertheless, the nature of the dialogue created in collaborative learning remains a key distinction given that students engage in social interactions in the co-construction of knowledge.

2.3.2 The collaborative approach to learning

Pedagogies that are underpinned by social constructivism are not new, but the implementation of change from traditional methods remains a challenge in many contexts (Mayer, 2012; Myllymäki, 2013; Quaye & Harper, 2014). Yadav, Subedi, Lundeberg, and Bunting (2011) explored the shift to learner-centred teaching by introducing problem-based learning into an undergraduate study in electrical engineering. They pointed out that over the previous decade or more studies have shown that although the work of engineers requires highly effective communication skills and the ability to apply their specialised knowledge in problem-solving at work, these skills may be lacking in new graduates. They also noted that recent statistics had shown an increase in jobs for engineers, but the rate of attrition is high for undergraduate students and thus has resulted in low graduation rates (citing National Science Board, 2008; see also Litzler and Young (2012); Malea and Bennettb (2014). Therefore, the way courses have been taught traditionally has been called into question, highlighting the contrast between the information-transmission view of learning through the monologic lecture talk and in-LAB isolated activity. The main problem in engineering higher education and engineering practices is a disconnection with practice. The university learning context typically provides a passive experience, such as in a lecture theatre or tutorial room (with the exception of the traditional Lab work); in contrast, engineering practice in the ensuing work is an active experience (Auer & Zutin, 2017; Palmquist 2007, p. 2). However, despite contemporary initiatives to improve the higher education LAB work learning, recent research into this issue by Panadero, Andrade, and Brookhart (2018) identified extensive attributes applicable to the learning experience and demonstrated that there is a strong need to explore the underlying pedagogy and how a more social constructivist approach might bridge the gap to improve learning and graduate completions. The design of learning in Lab work impacts pedagogy and, in turn, tutors'/supervisors' professional development and also impacts formative and summative assessment practices. According to Panadero et al.'s (2018) investigation, while the desired change in education may be achieved through learning based on problem-solving or project-based learning, all such approaches require students to participate in real-life, authentic learning experiences. Thus, in taking this into account, combined with the research into the importance of collaboration in adopting a social constructivist stance, the present research focuses on collaboration learning in the context of online learning and RALs.

Given that the essence of a social constructivist approach to learning is associated with teachers and students interacting together in the co-construction of new knowledge in order to better prepare students, they may first be involved in small-group tasks that focus on an engineering problem. This can serve as the preparatory work for an engineering design unit. This strategy, according to Odeh, McKenna and Abu-Mulaweh (2017), may involve making appointments with students during study time to facilitate full collaboration between students and trainers or tutors/supervisors, and encourage them to interact in the exchange of knowledge, questions and ideas. Applying the theory of social constructivism to facilitate learning design expertise that can ensure the learning and authentic use of the skills required by practising engineers is crucial to the LAB work learning context. The design needs to stimulate participants' effective communication to be able to collaborate and work successfully in a team environment, which is the core of real workplace practice, and involves cognitive, motor and emotional skills in line with those adopted by Feisel and Rosa (2005).

In addition, what is not discussed in this relationship in many educational curricula and social structural learning is the contrast with the traditional approach, which can be conceived as the transfer of information (Chandler, 2007), and the impact on modern interactive dialogic classrooms (Edwards-Groves, Anstey, & Bull, 2014; O'Neill, 2017; Van Es & Sherin, 2002). The importance of formative assessment is also neglected in relation to learning in higher education. However, recent research is beginning to recognise the need to focus on the features of the practice that allow checking for understanding along the way (Maier, Wolf, & Randler, 2016). Dann, Dann, and O'Neill (2018) make the distinction between formative evaluation that has the ability to "feed-forward" rather than "backwards" as in "feedback", thus progressing the teacher learning and teaching through an emphasis on bi-directional communication. This is in keeping with the practice of collaborative learning, which is dialogic compared with the talk associated with traditional instruction that is mainly monologic nature as in one direction of "information transfer only". Critics require teachers to be aware of the quality of the dialogue that classroom interactions/learning experiences create. O'Neill (2018, p. 75) states that this involves: "teachers being aware of their metacognitive processes in being able to formulate the most useful cognitive moves in the scaffolding of learning in response to the emergent dialogue with students". It is a similar situation in the context of teams working together to solve problems; there is a need to design learning experiences that stimulate constructive, critical dialogue. Much research has shown how the classroom dialogue can provide insights into the characteristics of scaffolding learning and practice that allows verification of the existence of understanding, and thus informs formative assessment (Kollöffel & de Jong, 2013; Leininger & Robinson, 1995).

As a guide to developing learning environments that can be effective in facilitating collaborative learning, eleven principles of learning experience design developed by Doolittle (1995) are well established. They comprise "eight structural principles to create engaging learning experiences" and clearly relate to the needs of formative assessment by considering Vygotsky's developmental approach in terms of students' ZDP (Reeves, Herrington, and Oliver, 2002, p. 564). They use characteristics of authentic learning activities as a basis for the development of guidelines on how to design and teach meaningful, engaging learning experiences. Thus, the present research chose to draw upon these guidelines to ensure that the rapid assessment of the functions of the design of the task and learning experience reflected "authentic activities to provide the opportunity to collaborate" (Reeves et al., 2002, p. 566). The following section further examines the evidence for the use of the Doolittle principles of learning experience design and presents a justification for the use of the Doolittle principles to underpin the research and provides an overview of the importance of each principle for the design of collaboration in Lab work.

2.4 Doolittle Principles – Support for Lab Learning Experience Design

Doolittle recommended principles that can help to design collaborative LAB work. Principle one advises to: *Teach using whole and authentic activities.* It highlights the need for a learning experience to directly connect to the real-world activity of an engineer's work. In the context of RALs, teaching methods and practices are based on technology that is accessed through the Internet. This means that access to remote control devices through a browser-based interface is necessary for all students' participation. They need to be able to work in the online learning space and use the relevant protocols, especially in a collaborative learning environment where roles and responsibilities need to be very clear. In the case of Lab work, such as in the present research, protocols that facilitate collaboration must ensure effective practice, including safety considerations; therefore, some preparation is required, as in the use of 'high-end' scientific simulation tools such as iLab (Harward et al., 2008) and Nano HUB Gateway (Zentner & Klimeck, 2016).

Importantly, as Gibbings (2014) recommended, the quality of experience in the field of RALs and the way in which they function depends on a variety of factors, including the efficiency of the technology and equipment. This applies in the case of any LAB, but also the design and creation of any learning experience, and where there is a need to connect to authentic professional work to facilitate collaboration and the opportunity for critical thinking and deeper learning.

The authentic activity element may take many forms: according to the goal of the project, learning activities may be connected to the real world because when dealing with problem-based learning it is important to address real-world issues that are relevant to the teaching objectives. Also, if the learning activity is connected to the real professional work context through the use of authentic methods, practices and audience, the learning should be more relevant. Communication with the real world, outside the laboratory via the internet, in addition to engaging in collaboration, is also seen as facilitating a connection to the real-life context with community members with mutual interests.

To have authentic experiences in such learning contexts, experts/tutors and students alike should be able to explore in a learning environment similar those that will be used in a real-life situation, including processes, facts, issues and knowledge. It should reflect such a realistic application of the knowledge of the circumstances relevant in this case to the teaching of LAB work in electronic engineering. Learning through exploration can occur in the classroom through strategies such as role-playing, independent workgroups or projects, and the use of computer simulation (Oliver, Herrington, Herrington & Reeves, 2007); however, the teaching of LAB work in RALs is especially challenged in needing to be authentic in what has been a highly protected practice in a traditional practice of working in the hands-on mode.

Authenticity in the design of both learning experiences and assessment, whether formative or summative, has received increased attention in recent years with the advent of the Internet and the uptake of learning in face-to-face and online courses in higher education (Dann & O'Neill, 2020). Herrington (2006) argued that the inherent value of the learning activity is not typically considered in the real-life context, but there are significant intrinsic activities that can be incorporated into the design of online courses to enhance the learning process. Sauter, Uttal, Rapp, Downing and Jona (2013) consider that one source of presence, as in a focus on realism, is particularly vital to make computer-based labs appear more like authentic, scientific places in which to experiment. Building in realism may be especially critical to students' learning because beliefs about the validity and authenticity of the technology may play a more significant role in Lab effectiveness than the technology itself (Lindsay & Good, 2005; Ma & Nickerson, 2006; Nedic et al., 2003). Across a range of applications, realism can be improved through design features such as photorealism (Daniel & Meitner, 2001). Sauter et al. (2013) investigated two factors that may influence students' learning and their sense of presence. These were (1) the kind of lab that was presented (remote lab or simulation), and (2) the inclusion of visualizations (photographs and videos). They found that improving the realism of a computer-based lab, either by utilizing actual equipment (such as with the remote lab) or incorporating more realistic visualizations, can enhance the authenticity of both the experience and learning outcomes. With the incorporation of these strategies it was found that students learning through the remote lab experience perceived it to be more like a real experiment, and they preferred to learn in RALs over the simulation experience (Sauter et al., 2013). Sauter (2011) also researched authentic learning experiences by using RALs and, likewise, found that students preferred them rather than the simulation. Moreover, it was found that the incorporation of visual representations added presence and made these experiences even more authentic and meaningful than that afforded by technology alone.

Nevertheless, according to Gibbings (2014), the reality of the remote laboratory equipment does not necessarily mean students will experience RALs in in-depth ways. He notes that the quality of the learning experience may depend on a number of factors such as the quality of the guidance provided for the activity, the relevance of the design experience and framing of the experiments to the context that makes the link to authentic professional work, and the extent to which the activities encourage students' self-reflection and contain authentic elements such as, camera and sound, and connections that build on students previous industry and other relevant experience. So realism is concluded to be a vital consideration and therefore needs to be considered in Lab work task design and, in the case of research design such as here, to investigate RALs. Sauter et al. (2013) reinforce this in noting that by creating an authentic online experience, RALs can help students to engage in scientific inquiry when the necessary empirical equipment is not locally available.

Task design has also been explored by Herrington, Reeves, and Oliver (2006) who recommended five characteristics that can be used to define a suitable case for investigation in research such as the present project. These are as follows:

1. Use of authentic, complex activities that form the core of the entire course.
2. Tasks meet at least six of the characteristics of authentic tasks listed on the list of authentic activity references (Reeves et al., 2002).
3. Courses must be a higher education course (graduate level).
4. Courses must be totally online and delivered at a distance (not a web-based supplement to an on-campus unit).
5. Courses must have run successfully for at least two semesters.

For example, the use of technology in authentic distance learning environments draws on attributes of technology use that relate to the real-life nature of the activity and the seamless and integrated applications for communication and knowledge construction that the technology must provide.

Doolittle's (1995) second principle specifies a need to: *Create a 'need' for what is to be learned*. This relates to the importance of students being able to have agency within their learning. Williams and Williams (2011) note the importance of students being involved in positive learning experiences so that they are motivated to participate.

Since LAB experience has a feature that allows students to put theory into practice immediately, whether it is learning in hands-on or in RALs, although it may be mediated through technology, it is highly likely to be experienced positively—unless of poor design. Again, the adoption of a problem- or project-based learning may be applied to meet this requirement.

Similarly, Principle three states to *Create classroom exercises that require social interaction with peers, parents, teachers, or professionals.* This principle is highly relevant to learning collaboratively in RALs. It can be achieved through learning experiences that aim to facilitate peer interactions and collaboration to address a clear relevant goal that is linked to the authentic practice of the relevant engineering work in the context of the present research. Also, in line with the views of structural learning and support, social interaction, in the context of the exchange of ideas about a particular problem or experiment, can accommodate this principle. In turn, learning experiences can be designed to encourage practices that encourage critical reflection of the task and create behaviour change and cognitive change—and ultimately student agency and independence in learning (Doolittle, 1995; Gagné, 2009).

Examining this pedagogical approach of collaborative learning in more depth, Principle four is: *Encourage self-talk or egocentric speech*. This principle acknowledges the role of the learner and the metacognitive processes that effectively-designed collaborative processes should facilitate to develop students' problem-solving skills. Doolittle (1995) recognised that talking to oneself or thinking out loud is an effective tool that people use to solve problems and that this needs to be made explicit to all in the teaching-learning process. Appreciation of this metacognitive strategy also supports students' personal cognitive and metacognitive awareness and development, since, as Vygotsky believed, when expressing thoughts aloud, and in the case of engineering students, ultimately internalization becomes part of the problem-solving strategies they use. The adoption of this strategy is also likely to contribute to the development of students' self-control in line with the need to take a professional approach to solve problems in the workplace.

Principle five notes the importance of *Providing opportunities for verbal interaction*. This is core to the design of any learning experience underpinned by social constructivism, and certainly in the design of collaborative learning experiences in RALs. This is because it allows students and teachers to freely question and discuss the task or problem to be solved, wherein traditional teacher-centred pedagogy students are less likely to participate in dialogue—rather, it is more likely that the teacher's talk features in the lesson for close to 80% of the time (Hattie, 2012). As Pais Marden and Herrington (2011) emphasise, the use of language in situations involving patterns of behaviour, being interactive and in facilitating cognitive processes/thinking, mental functions and restructuring processes to absorb new knowledge and skills can, in turn, facilitate opportunities for learners to move forward through the area of their learning and development in keeping with their ZPD. This leads to the sixth principle, the importance of formative assessment during the learning cycle: *Closely monitor student progress in order to avoid assigning tasks that are not within a student's zone of proximal development.* This principle is necessary to ensure that the tasks are set at the appropriate level to advance students' learning. Therefore, the learning design needs to include a breakdown of the task into sub-tasks or skills to support and document the learning process in relation to the learning objectives to allow formative assessment for each student, as noted by Maier et al. (2016), and a requirement to identify feedback markers (Dann & O'Neill, 2020). Thus, these signs need to be formative rather than summative to monitor and best support individual students' learning. Further to this, Principle seven notes that *Instruction or activities must precede a student's development.* This is crucial to facilitate learning because if the experiences presented are too difficult for students to achieve the target this will hinder their learning. Thus, the task should be designed to have a comprehensive awareness of the students' existing knowledge and skills and build in preparation for the development of new applications and any new knowledge and skills needed to master the task/s in focus. The learning experiences should be designed so that students' abilities evolve in order to control this target task. The eighth principle is important as it alerts the designer to the need for students to experience initial success. This principle advises to *Present tasks that students can perform successfully with assistance.* This principle emphasises the importance of making assistance available to students and the need for them to be aware of its availability. Principle nine relates to the importance of learning support in emphasising the need to: *Provide sufficient* *support to enable the student to perform challenging tasks successfully, and then gradually withdraw support as the student becomes more skilled*. It recognises that while there may be a need for assistance in the beginning, as the learning progresses this can be gradually withdrawn—although some elements of the challenge will be necessary to maintain students' interest and motivation. The fact that learning experiences should be real-world experiences associated with the work of engineers means that students should have the opportunity to take responsibility for the implementation of tasks independently, as well as in collaboration with others in the LAB experience.

An additional important aspect of the learning experience is Principle ten, which notes: *Students must be given the opportunity to demonstrate learning independent of others.* This principle is a reminder to avoid losing sight of the fact that each team member in the collaborative learning process needs to acquire and demonstrate the planned knowledge, skills and understanding by themselves. To achieve this independence, students need to have the opportunity personally to carry out the activities to build their confidence and self-efficacy as engineers. Thus, the distinction is the nature of the learning experience, which is vital to the learning process as it needs to link closely to supporting the formative evaluation of continuous learning design and the formative and summative assessment design. Finally, closely aligning with Principle ten is Principle eleven which advice: *Construct activities that are designed to stimulate both behavioural changes and to meet cognitive changes.* This emphasises Osberg's (1997) view of the need to provide learning experiences within a structured framework that connects the various behaviours that students need in order to enhance their learning outcomes. On this basis, designers/teachers need to obtain the necessary planning and organizing skills to be able to ensure that students have the opportunity to learn and demonstrate successful learning outcomes. In this way, it is expected that the students' learning experiences will allow them to grow and build knowledge independently, as well as develop their practical skills and abilities. Table 2.1 summarises the 11 principles and their focus.

Table 2.1

Doolittle's Eleven Principles of Learning Experience Design and their Brief Description

Doolittle's Principle	Brief description
1. Teach using whole and authentic activities.	Collaboration on learning activities should be genuine, not contrived or artificial.
2. Create a "need" for what is to be learned.	To increase motivation and positive effect, students on collaboration have to see the need for learning activity
3. Create classroom exercises that require social interaction with peers, parents, teachers, or professionals.	Designing collaboration Activities should be structured to foster interaction between group members.
4. Encourage self-talk or egocentric speech.	Encourage the student to think aloud and think to themselves during solving problems.
5. Provide opportunities for verbal Interactions.	By the Language students can plan their behaviours, to understand another's thinking.
6. Instruction or activities must precede a student's development.	The leader needs to closely monitor students in collaborative groups to ensure that each student is being sufficiently challenged and to determine each student had learned the intended material.
7. Present tasks that students can perform successfully only with the assistance	Collaborative learning on activities should be designed to lead a student to new knowledge and understanding. Tasks should be constructed at the upper end of each student's zone of proximal development so that the student must develop in order to master the task.
8. Provide sufficient support to enable the student to perform challenging tasks successfully, and then gradually withdraw support as the student becomes more skilled.	Students should be presented with tasks that require outside help or assistance. By presenting activities that require the student to seek assistance, the activity will lie within the student's zone of proximal development and will foster social mediation.
9. Students must be given the opportunity to demonstrate learning independent of others.	Students begin to learn the task in which they need help take over so that the student may take more than the responsibility to carry out the task independently.

Doolittle’s Principle	Brief description
10. Construct activities that are designed to stimulate both behavioural changes and cognitive/metacognitive changes.	Students should be allowed to attempt an independent activity by giving the task to complete an independent and it also provides a means for assessing a by teacher or leader to determine if the student has mastered the task at hand.
11. Closely monitor student progress in order to avoid assigning tasks that are not within a student's zone of proximal development	Activities should be organised to develop not only the ability to perform certain behaviours, but also the ability to plan, organise, and control behaviour.

In support of the application of these principles, Herrington, Reeves, and Oliver (2009) provide comprehensive guidelines focused on learning the basics of design and the importance of authenticity. In the context of the present research, it is concluded that the Doolittle eleven principles of learning experience design and the depth of insights they provide into the design of learning tasks for collaborative learning make a strong and valid basis for the present research. These principles are used in designed RALs in the exploration of engineering students’ learning with respect to the operation of the Voltage Divider in electrical engineering.

2.5 Collaboration in Remote Access Laboratories

Collaboration in remote access laboratories allows students to perform practical experiments remotely in a collaborative way and to engage with other students. This type of collaboration is seen as a practical approach to improving and supporting educational outcomes (Koo, 2008; Moeller & Reitzes, 2011). People generate knowledge and meaning when they share their ideas and experiences, plus they also benefit from the social interaction (Al-Ammary, 2013). Another benefit is the increase in motivation stemming from active learning in a collaborative environment. This approach has already demonstrated a positive effect on students in laboratory sessions (Aziz, 2011; Bochicchio & Longo, 2009; Brooks, 2011; Gravier et al., 2012; Jara et al., 2012).

Collaboration is most important in terms of teamwork. In the past, remote laboratory students felt isolated because they may have been unable to share knowledge of the case in hand since they have limited opportunity to collaborate in the traditional laboratory setting (Odeh & Ketaneh, 2013). Furthermore, they may be denied the opportunity to interact and share information and experiences. In the absence of communication, students tend to feel isolated, and such a disadvantage could affect their learning efficiency (Bright, Lindsay, Lowe, Murray, & Liu, 2008). A collaborative environment will encourage students to undertake speed of interaction; and experience clear articulation of expectations and timeliness of feedback. Also, it enables them to have access to more additional hands-on laboratory experimentation by sharing ideas and interacting, and have the opportunity to discuss results and enhance outcomes (Aktan, Bohus, Crowl, & Shor, 1996). Through this process, students can debate the results of their experiments, support one another and create an environment of fellowship and collaboration. Collaborative learning is an excellent opportunity for more effective outcomes and allows the user full control and freedoms over their learning—which will encourage students in an active learning process (Ma & Nickerson, 2006). Students in remote laboratories need to be in a collaborative setting because, in conducting experiments, it allows students to compare their findings and attempt to justify the differences between them—which, in turn, leads to more accurate outcomes (Machotka, Nedić, & Nafalski, 2011).

Another benefit of collaboration activity is that students and teachers can discuss findings that may be flawed, and students have the opportunity to address any errors (Maarouf et al., 2012). Moreover, a remote laboratory environment provides collaboration capability between peers (student-to-student communication and student-to-teacher communication) that make the experiment more comfortable to conduct and understand. Laboratory work conducted through remote collaboration can play a vital role in learning. Notwithstanding the progress already made in the traditional (hands-on) laboratory and based on teamwork, it has lacked the features of collaboration offered by remote laboratories (Lowe et al., 2009).

Effective teamwork is one of the most critical aspects of engineering and science courses. Students in remote laboratories who are learning excellent collaboration skills with other national and international students can enhance their prospects for professional employment in the global market because the remote laboratory is a unique platform for collaboration and networking (Nafalski et al., 2009). Lab shared projects have demonstrated that remote laboratories could be expanded or extended worldwide to thousands of students (Harward et al., 2008). The collaborative approach is an added advantage to the remote laboratory, and an improvement over the hands-on and simulation laboratory as interaction is more natural in remote access laboratories than face-to-face—which is seen as an essential characteristic of the profession into the future (Nafalski et al., 2009).

Another advantage of collaboration in RALs is that collaboration via remote laboratory offers enhanced learning as students can focus and mirror other students' ideas rather than concentrating on technical issues. This element has been a disadvantage for hands-on laboratories in which students tend to focus on technical activity with respect to interaction with the central technical concept. That means that students will not experience laboratory time to express their ideas and analyse their form of inquiry (Ma & Nickerson, 2006). From another viewpoint, in the remote laboratory, technical issues (such as the setup issue for the experiments) do not arise, and the students can concentrate and ponder their experiments—which leads to critical and coherent thinking. This collaborative learning style in engineering and sciences could also benefit research generally (Ma & Nickerson, 2006).

Many researchers focus exclusively on developing ways to facilitate collaboration in remote laboratories. For example, Jara et al. (2012) proposed a project which creates a framework and a toolkit to be disseminated across the Australian higher education sector, and internationally, to be used to support student collaborative activities in remote laboratories in a structured way. Jara et al. (2012) presented a new system to share practical collaborative experimentation through the internet, based on virtual and remote laboratories (VRLs). Their system combines the main advantages of VRLs and the synchronous collaborative learning practice, where the VRLs are based in Java applets developed in Easy Java Simulations (EJS), and the collaborative online learning framework is a synchronized communication in real-time. However, Jara et al. (2012) work centres on peer-to-peer collaboration, not peer (group) collaboration—which is the focus of this current research.

2.6 Computer-Supported Collaborative Learning

Since the 1990s, computer-supported collaborative learning (CSCL) research has typically focused on online networks for facilitating and recording online interactions between two or more individuals who may be geographically dispersed (Kapogiannis & Mlilo, 2019; Lai, 2011; Zamiri & Camarinha-Matos, 2019). Much of this research has grown in parallel with new technologies for supporting distance/synchronous interactions, such as email, instant-messaging capability and, more recently, resources for synchronous video conferencing such as Skype, Google doc, Zoom, and the like.

Collaborative learning environments that place importance on the process, rather than a product, engender this type of interactive learning (Herrington, 2006). The traditional form of such collaborative learning has been via face-to-face groups working together (Ellis, 2001). The online forum can provide a different collaborative learning environment, due to its student centres, asynchronous/synchronous, and written form (Dixon, Dixon, & Axmann, 2008).

Constructivism is a theory that explains why collaborative learning is useful and how it works. In this approach, learning emerges from the interaction of individuals with other individuals (Benbunan-Fich & Hiltz, 1998; Isohätälä, Järvenoja, & Järvelä, 2017). Learning occurs as individuals exercise, verify, solidify and improve their mental models through discussion and information sharing during the problem-solving process (Alavi, 1994; Leidner & Fuller, 1996; Rentsch, Delise, & Hutchison, 2008; Savolainen, 2017); and as team members engage in shared teaching.

Exercises during activities are an effective way to engage students in problem-solving activities that challenge mental models and allow their refinement. The goal of the cases is to enable students to process instructional inputs and assimilate the course material. Such cases can be analysed individually or in the context of a group (Foulkes, 2018).

When problem-solving takes place in a group setting, higher-order cognitive skills are developed (Csapó & Funke, 2017). Moreover, the contribution of different understandings or exposure to alternative points of view can enhance learning. Thus, the discussion and solution of case scenarios in groups may accelerate the creation or refinement of improved mental models and augment learning (Benbunan-Fich & Hiltz, 1997).

Collaboration and teamwork can support the development of advanced mental models for several reasons (Benbunan-Fich & Hiltz, 1997). First, there is an opportunity for evaluation and feedback where group members can monitor individual thinking and provide feedback for clarification and change. Second, exposure to alternative points of view can challenge understanding and motivate learning. Third, a group structure offers social support and encouragement for individual efforts.

Doolittle (1995) synthesised the work of several social constructivism theories to produce eleven principles of learning experience design in the classroom. This researcher used this work to transfer the principles to an online environment as a means of developing a framework to enable collaboration in the online environment—a suitable basis for developing principles specific to Remote Access Laboratories collaboration.

2.7 Fundamental Elements of Collaboration

2.7.1 Kagan PIES

Kagan (1992) developed approximately 200 classrooms ‘structures’, which may be thought of as steps to classroom activities and devised four essential outcomes of collaboration based on his structural approach to collaborative learning. These outcomes are seen as essential to collaborative learning and are referred to using the acronym PIES as follows:

Positive Interdependence

Individual Accountability

Equal Participation

Simultaneous Interaction.

For collaborative learning groups to be active, all four of these essential elements must be present. It is through PIES that groups are managed and assessed. Positive interdependence is successfully structured when group members perceive that they are linked with each other in a way that one cannot succeed unless everyone succeeds. The group must be accountable for achieving its goals, and each member must be responsible for contributing his or her share of the work (Johnson, Suriya, Yoon, Berrett & La Fleur, 2002). Also, the participants should be equal, and all participants working simultaneously. This research project uses Kagan's (1992) essential elements as evidence that collaboration occurred as an outcome. When these elements are present, then it can be argued that true collaboration occurred; thus, if any are absent in terms of Kagan's view true collaboration would be unachievable. They also indicate that the collaborative work may also be teamwork. Table 2.2 shows the four outcomes, the questions each can address and type of evidence of engagement.

Table 2.2

Kagan's PIES Four Outcomes of Collaborative Learning

Elements (PIES)	Questions	Increase active engagement
Positive interdependence	Does the success of one benefit other? Is everyone's contribution necessary?	Students encourage and tutor those who otherwise might give up. Every student's contribution is necessary.
Individual accountability	Is individual, public performance required?	Students who otherwise would not participate are required to respond.
Equal participation.	How equal is participation?	Shy and weaker students are given equal time.
Simultaneous interaction.	What per cent are interacting at once?	Per student, active engagement is increased dramatically.

2.7.2 Dillenbourg's elements of collaborative learning

From the perspective of the actual collaborative activity, Dillenbourg (1999) highlights a further four elements that this research should take account of in its intention to engage students in collaborative learning. In providing a description of elements and theory to explain the collaboration, Dillenbourg (1999, p. 9) notes, "a situation is termed 'collaborative' if peers are (i) more or less at the same level and can perform the same action, (ii) have a common goal, and (iii) work together". Creating collaboration is seen as needing to consider the four basic elements of the situation, the interactions, the learning processes and effects. Also, it is important to consider how collaboration can be an interpretation of the complex relationship that links these elements together. These elements are further explained below:

Situation: The context of learning becomes collaborative when students have similar levels of procedures, knowledge, situation, and goals; and collaborative work (Almajed et al., 2016). However, the similarity of experience and benefit can still accommodate slight differences in students' knowledge and inconsistency in their opinions.

Interactions: There are different methods of interacting collaboratively, that is, 'interactive', 'synchronising', and 'negotiable' (Dillenbourg, 1999, p. 11). Specifically, collaborative interactions can influence group members' learning processes concurrently by organising each other's logic and communications. In addition, having a negotiable space allows for discussing, justifying and negotiating without students imposing their opinions.

Learning Processes: It is important to consider the learning processes, and how learning will occur in a cooperative/collaborative context. For example, when there is ‘horizontal’ division of tasks the divided parts may still be connected and dependent on each other, and undertaken collaboratively (Almajed et al., 2016). The challenge of learning through experiment and grappling together with new knowledge typically occurs in the collaborative learning process, in which negotiation and justification of argument can help to develop student learning.

Effects: Importantly there is an need to consider this element as it represents the effects of the various factors involved in the learning situation and in turn the quality of the collaboration (Almajed et al., 2016). For example, different learning processes and ways of fostering and guiding students’ constructive interactions may impact on students’ learning success. Dillenbourg's (1999) four elements of learning applicable to collaborative contexts for learning, are shown in Table 2.3.

Table 2.3

Dillenbourg’s Elements of Collaboration Learning

Elements	Description
Situations characterized as "collaborative"	Symmetry on (action, knowledge, status share common goals and work with each other)
Interactions characterised as "collaborative"	Interpersonal activity (The degree of negotiability (arguing, justifying, negotiating and convincing, and synchronising).

Processes characterised as "collaborative"	Interpersonal cognitive process, social contexts (cognitive conflict).
Effects of collaborative learning	Conceptual change and outcomes.

2.8 Formative Assessment and Learning

Wiliam (2011) relates formative assessment (FA) to how data can be presented during the learning process in a form that can be used to facilitate and improve students' learning and the teacher's teaching. This formative approach is in contrast students completing only summative assessment such as a final end of course achievement test where the results are too late to enhance their course learning. To best support students' learning during their study they require data on their learning that can feed forward to improve (Dann & O'Neill, 2020). Brookhart (2013) identifies two distinguishing descriptive assessments as an adjunct in learning and achievement that enable assessment of the goal of learning. Panadero et al. (2018) also highlight the relationship between learning theory, self-regulation and the role of formative assessment, thus reiterating the critical role of learners in their learning, besides the need for observations or data on the progress of their learning to 'feed-forward' (citing the Council of Chief State School Officers (SCASS, 2012). They stress how the impact of evaluation on learning needs to be considered from a psychological and social point of view, stating:

> Examining the psychological and social effects of FA helps to understand what happens with SRL. What types of mental and emotional processes do students activate during self- or peer assessing? How do those processes influence the activation of learning strategies? Interest in this type of research is growing, as demonstrated by the publication of a new handbook on the human and social factors of assessment (Brown & Harris, 2016). Only by understanding internal cognitive and affective processes, we can truly understand the power of FA (Panadero et al., 2018, p. 28)

The implementation of formative assessment involves the use of information retrieval cycles to evaluate and interpret the information collected and to build on this information to improve teaching and learning processes.

In addition, Poth (2018) notes that formative assessment may also involve interaction between teachers and students and their peers, and allows instructions to be interpreted, applied and modified to guide students and support their learning outcomes. In the call for Advanced Technology Formative Assessment (TEFA) they recognise the complexity of learning environments and purpose teaching, noting that "we are only beginning to recognise emerging features in a learning environment that explicitly achieves understanding and then supports learning through adjustments in education" (n.p.).

Further, Poth (2018) cites Maier et al. (2016) regarding awareness of how TEFA has the capacity to support and facilitate the provision of such features and ultimately contribute to improving the quality of learning environments in higher education. The design of learning experiences is, therefore, a challenge in ensuring that teachers can respond to the need for appropriate feedback marks.

Panadero et al. (2018) outline six features that are critical to the design of practical formative assessment, taken from the Council of Chief State School Officers (2012), as follows:

> *Learning progressions:* Learning progressions should clearly articulate the sub-goals of the ultimate learning goal.
>
> *Learning goals and criteria for success:* learning goals and criteria for success should be clearly identified and communicated to students.
>
> *Evidence of learning:* Evidence of learning is elicited during instruction.
>
> *Descriptive feedback*: Students should be provided with evidence-based feedback that is linked to the intended instructional outcomes and criteria for success.
>
> *Self- and peer assessment*s: Both self- and peer assessments are essential for providing students with an opportunity to think cognitively about their learning.
>
> *Collaboration:* A classroom culture in which teachers and students are partners in learning should be established (Wylie & Lyon, 2016).

These qualities are in line with Feisel and Rosa's (2005) targets for the design of The collaborative approach to learning experiences and related to the communication and teamwork in reference to the need to cooperate and work with their peers. Thus, the educational approach becomes one of the primary considerations in the traditional approach to the work of LAB, which usually saw students working in isolation from each other, and was seen as needing to have students involved in learning together.

Although the use of technology in online learning has been implemented in the field of higher education for many years, Poth (2018) notes that the debate still centres on whether there are significant differences in the effectiveness of student learning asynchronously compared with those that learn simultaneously (able to communicate with each other in real-time). Poth (2018) cites the research of del Mar Sánchez-Vera & Prendes-Espinosa (2015) in noting that:

> "On-demand access has led to the creation of masses of digitized lectures and learning activities and a marked increase in research that is assessing student experience and impacts on learning; for example, there has been an exploration of alternative means of assessment in massive open online courses, MOOCs" (n.p.).

However, Poth's (2018) findings show that the investigation contends practice online formative assessment strategies that advanced technology can support students' motivation and learning self-regulation, which is inherent in learning for both immediate and long-term success. It concludes that formative assessment strategies, advanced technology is an important contributor to the creation of continuous evaluation of systems where learning and evaluation go hand-in-hand and provide an opportunity for students to pay attention for their learning. This analysis confirms the need for educational change towards the point of view of social constructivist learning where Feisel and Rosa's (2005) objectives can be addressed more comprehensively in the LAB learning experience. A collaborative approach to learning would be central to bringing about this change. Thus, it must be noted that the approach to education and this formative assessment depends on the implementation of a more student-centred approach where students have the opportunity for discussion in the context of problem-based learning. It may involve peer assessment and self-assessment, as well as evaluating the group that focuses on collaborative tasks. Such tasks as planned in this research require minimal resources to support students in the assessment and peer assessment, yet are able to ensure that the information is sound and helps encourage students to self-regulation (Boud, 2013).

2.9 Gaps in the Literature

Several studies have examined the link between learning outcomes and online collaboration in education (Islam, Rahim, Tan, & Momtaz, 2011; Kreijns, Kirschner, & Jochems, 2003; Spears, 2012). Limited studies have been conducted on the evaluation of collaborative learning in remote laboratories. This does not come as a surprise because a vast majority of remote laboratories are designed as single-user laboratories, and student collaboration is not possible (Broisin et al., 2017b; Gleich et al., 2019; Nafalski et al., 2009). However, the use of collaborative technologies in learning has received considerable attention in recent years. Still, few studies to date have investigated the components of environmental requirements for collaboration to occur, or inhibitors that affect collaboration in remote laboratories. A study conducted by Huang (2015) shows that learners with different learning styles have different needs for educational technologies. Accordingly, investigating the extent to which engineering students received collaborative learning in RALs as a workable alternative to traditional LAB work is vital. Also, identifying the key factors likely to influence the adoption of such pedagogical change, including factors to be considered when planning to adopt collaboration in RALs and online in the use of collaborative technologies, are essential issues.

2.10 Summary

This chapter has provided details of the literature relating to collaboration in the remote access laboratory. The chapter began by providing an overview provided a general explanation of the remote access laboratories. It then explained the environmental classification of the laboratory, followed by the types of laboratory experiments. In this section, the present research was classified as a laboratory experiment and forms the language of the nature of experience (real/virtual), and the place to control the user experience (local/remote). This review provided a comprehensive picture of existing scientific research of laboratory and environmental types, including existing scientific studies of inquiry-based learning and collaborative learning in the design of a laboratory task that included discussion on collaboration, coordination, and a collaborative approach to learning. This guided the design of the LAB learning experience and considered Doolittle (1995) and the fundamentals of social constructivism in the formulation of eleven principles of learning experience design. I addition, the relationship between cooperative laboratories and collaboration in remote access laboratories was explained and the theoretical bases of collaborative learning design and outcomes were presented. Besides the importance of the Doolittle principles the theoretical framework identified of Dillenbourg's (1999) four key elements of collaboration and Kagen's (1992) four outcomes of collaborative learning. The chapter also raised the issue of the importance of formative assessment in learning, including its relevance to how data can be presented during the learning process to facilitate and improve learners' learning and teachers' teaching. This was followed by the identification of gaps in the literature based the chapter's investigation of prior studies on the link between learning outcomes and online collaboration in education. In conclusion it was found that further research is required to investigate the implementation of collaborative learning in remote laboratories. This did not come as a surprise because the vast majority of remote laboratories are designed as single-user laboratories where student collaboration is not possible. However, the use of collaborative technologies in learning has received considerable attention in recent years, but few studies to date have investigated the components of environmental requirements for collaboration to occur or inhibitors that affect collaboration in remote laboratories, where this represents a paradigm shift in pedagogical approach. The next chapter, Chapter 3, describes the design procedure used to set up the RAL.

Chapter 3 ACTIVITY DESIGN

The previous chapter provided comprehensive details of the literature related to collaboration in a remote access laboratory. This chapter, Chapter 3, describes the design procedure used to set up the RAL. The chapter is organised into eight sections. Section one is an overview of activity design, followed by a description of the activity in Section two. The third section illustrates the activity design (Voltage Divider Experiment). The remaining sections focus on activity requirements, learning objectives, application to activity and challenges; and then details the last aspects of the procedures in terms of worksheet instructions and guidelines.

3.1 Constructivist Principle for Activity Design

Transfer from face-to-face mode to online mode took these principles on board. These principles have been developed by Doolittle (1995) using Vygotsky's social constructivism theories, and the researcher used them as a basis for developing principles specific to RAL collaboration. The eleven principles of learning experience design recommended by Doolittle (1995) are described in the following subsections.

3.1.1 Teach using whole and authentic activities – Principle One

This principle advises on the importance of establishing a context for learning that reflects the real-life situation in which knowledge and skills are to be applied. It emphasises the need to provide learning more realistically and maintain the reality of the problem involved so that it can reflect the real complexity. Moreover, it highlights the need for students to learn more about what they have learned, and be aware of the new skills they have acquired, besides being allowed to have input into extending the learning, an aspect which is viewed as significant (Lombardi, 2007). This principle can open an opportunity for students to think more in the course about their learning and the environment in an authentic context. In many educational settings, and traditionally in Lab work, there are typically limited opportunities for reflection owing to the need to concentrate on procedures and more teacher-centred approaches to learning. Subsequently, a lack of opportunity for student interactions and collaboration means that students cannot reflect socially.

This principle also draws attention to the learning activity being ‘whole’. This is also significant for ensuring an authentic opportunity for both the learning task design and the use of the collaborative approach to learning (Lombardi, 2007). An authentic task requires students to work in small groups, typically up to five members, to support collaboration via the Internet, such as in RALs (Oliver et al., 2007). The present research considered this principle. As a result, there is a need for the task design to be representative of the work of engineers and be holistic and able to be facilitated online in the RAL environment. As recommended, ill-defined activities or tasks that are presented in an unconnected or unauthentic way for students to be able to master over a sustained period would be detrimental to students’ learning. Thus, the activity design for the present research involved a “whole and authentic activity” by selecting the Voltage Divider Experiment using LabVIEW software to provide the ‘real’ Voltage Divider. The Voltage Divider is a passive linear circuit that produces an output voltage that is a fraction of its input voltage (Hopkins, 2018). Northrop (2012) suggested that it is essential for engineering students to understand the purpose of and acquire the skills to use the Voltage Divider in their work because most electrical and electronic equipment uses voltages of different levels throughout their circuits. A single circuit may require many voltage levels to work correctly. Many individual power sources can supply these voltage requirements. This method is expensive and requires a great deal of space and the equipment resources required for this purpose is also substantial. The most common way to supply this voltage is to use a single voltage source which is a voltage divider. This circuit can divide one supply voltage into many other supplies. For example, the necessity of equipment 10 volts, 5 volts, and 30 volts using the voltage divider circuit instead of three circuits individually can cover these different levels of voltage levels. Such the voltage divider can provide not only the best and most accurate signal, but it is also much smaller in overall dimensions, more standardized, more secure and less expensive (Milovac, Javora, & Skendzic, 2017).

The above discussion shows clearly the relevance of applying Doolittle’s first principle in researching the RAL learning environment. To make the learning experience authentic or situated in the students’ real world is a crucial aspect of task design to ensure student collaboration can occur. As espoused by Doolittle, to enable authentic learning experiences in RALs involves selecting the learning activity and devolving it as an authentic activity and keeping a checklist as evidence if necessary. Designing authentic activities properties can elicit a list of useful guidelines espoused by Reeves et al. (2002, p. 564) to demonstrate authenticity in a remote access laboratory:

> *Authentic activities have real-world relevance,* matching as nearly as possible the tasks of professionals in practice (Brown, Collins, & Duguid, 1989; Cognition and Technology Group at Vanderbilt, 1990; Cronin, 1993; Jonassen, 1992; Lebow & Wager, 1994; Mattar, 2018; Omari, 1999; Winn, 1993).

The researcher in this study used video conferencing tools (collaboration tools) to support the collaborative learning experiences. Taking this principle into account means that in developing a practical activity, it is important to make regular adjustments based on students' feedback and observations as it is trialled and implemented in RALs. Such activities should be designed to encourage ways of thinking that would be expected in real-world workplaces and the management of experimental components. The use of the video conferencing tools enabled the planning and the adaptation of learning experiences.

The collaborative learning activities were complicated, as they took an experimental approach and required students to find associations between variables that were not explicitly linked. They needed to derive their research questions after they had discussed the circuit connection, calculated the resistance amount and also the output voltage. The result could be later compared with the measured output voltage and student could then create their personal notes using the conference tools. This involved synthesising the information they found and summarizing the results. The appropriateness of the task for this principle is in keeping with the various researchers who emphasise how authentic activities comprise complex tasks to be investigated by students over a sustained period of time (Bransford, Vye, Kinzer, & Risko, 1990; Cognition and Technology Group at Vanderbilt, 1990; Jonassen, 1992; Lebow & Wager, 1994).

Each activity was planned to run over a week, with students and the researcher meeting online and interacting via the conference tools. These were used to supplement the online collaborative discussions. Importantly, the task (practical activity) was not an isolated activity, since the conference tool was able to facilitate communicative interactions between the remote laboratories. At the same time, students engaged in research and content creation, and the researcher and students/peers give feedback on the students’ conference tool and took notes. This principle raised the issue of students requiring adequate time to learn a complex task such as planned, since they also needed to be prepared on their computers. This principle was therefore important advice for the design of the present research into RALs, since the degree of complexity of the task needed to be clarified and consideration given with regards to the adequacy of the learning experiences and time allowed.

It is also noted that authentic activities provide the opportunity for students to examine the task from different theoretical and practical perspectives, using a variety of resources that require them to critically evaluate information (Bransford, Sherwood, et al., 1990; Bransford, Vye, et al., 1990; Cognition and Technology Group at Vanderbilt, 1990; Jonassen, 1992; Sternberg et al., 1993). Such activities also provide an opportunity for group work (Gordon, 1998; Lebow & Wager, 1994; Young, 1993) and can be integrated and applied across different subject areas besides lead beyond domain-specific outcomes (Bransford, Sherwood, et al., 1990; Bransford, Vye, et al., 1990; Jonassen, 1992).

Thus, activity notes were developed collaboratively by the student groups, and all notes were made available to the other group members, as well as to the researcher. Each day, students created summaries of their activity using the slideshow component of the conference tool, presenting this in the RALs context, and then sharing in the reviews with everyone. The conference tool also featured an instant messenger, which allowed students and staff to discuss aspects of the activity notes while looking at the document together, from their different remote locations.

The researcher’s feedback to students within their activity notes included comments and questions to encourage them to reflect on their reasoning and identify any assumptions. This facilitated students being challenged on their statements and encouraged them to articulate their understanding, as the questions were not asked to elicit information but, rather, to stimulate further thinking.

Each activity was designed to integrate research, ethical reflection, and knowledge from their course learning modules but not exclude their experience. The activity was designed so that it would not be an isolated activity that would be separate from other modules, thus seamlessly integrated with assessment (Herrington & Herrington, 1998; Reeves & Okey, 1996; Young, 1993). Thus, formative assessment was considered an inherent part of the activity, where peers and researchers could regularly challenge statements and assumptions that might arise during the class sessions, and in the online notes. Students and the researcher were able to make comments via the conference tool and ask questions regularly. The notes that were created in the conference tool constituted the students' content for the module, making them a critical product of the task.

In keeping with the literature that notes authentic activities as allowing competing solutions and diversity of outcomes (Bottge & Hasselbring, 1993; Bransford, Sherwood, et al., 1990; Bransford, Vye, et al., 1990; Duchastel, 1997; Young & McNeese, 1993) provision was made for each group's online activity notes to be different, thus reflecting the questions to be answered after exploring their understanding of the activity. The researcher's role included ensuring that the primary concepts were addressed; however, students were still able to take their own routes to achieve the objectives.

3.1.2 Create a 'need' for what is to be learned - Principle Two

It can be appreciated that Doolittle's (1995) second principle was vital to the design of the present learning activities and the tasks involved. This principle is very much linked to the need to motivate students to learn. If the focus is on learning that appears to have little relevance, then students would be unlikely to be enthused with some learning situations. However, if more formal testing was involved, their attention may be more linked to such extrinsic motivation. Thus, with this principle, Doolittle, in keeping with the need for real-life, work-related tasks and the need for authenticity, emphasises the need for creating a learning environment that fosters students' intrinsic motivation. Therefore, by selecting the Voltage Divider Experiment, the researcher presented an activity where the students were not only able to use the apparatus as they would in a 'hands-on' Lab mode, but were able to experiment without fear or risk of something untoward occurring. Thus, this principle was achieved by increasing the influence on student learning through realism, and ensuring the experience was positive and motivating in terms of its relevance to the course learning objectives (Williams & Williams, 2011). The research activity design, therefore, took account of the need for deepening students' learning through the direct relevance to Lab work, and the ability to facilitate online collaboration. This aspect helped them understand the theory they had studied in engineering practice lectures and gain experience in understanding problem-solving and the manipulation of variables.

3.1.3 Create classroom exercises that require social interaction with peers, parents, teachers, or professionals. Principle Three

Creating classroom exercises can increase social interaction with peers or professionals. Collaborative activities should be structured to promote interaction between group members. Such social interaction allows students to exchange ideas and experience new behaviours through expression and by internalizing those ideas (Gagné, 2009). It also provides the opportunity for oral interactions; and for construction activities that are designed to encourage both behavioural change and cognitive change (Doolittle, 1995). Constructivists encourage strategies such as collaborative learning and conceptual change through the development of independence and autonomy In learning (Falchikov, 2001). The Voltage Divider Experiment was structured to enhance interaction between group members. Each student was required to interact socially with whoever carried out the task and had a responsibility to calculate the output effort, and compare it with the results of experiments and discuss the result with other students. Discussion and social interaction between students allowed them to exchange results, compete for points and consider other people's ideas.

3.1.4 Encourage self-talk or egocentric speech - Principle Four

The encouragement of self-talk or egocentric speech is important as it facilitates metacognitive processes, thinking about thinking, and supports students' development of higher order critical thinking when involved in motivating learning experiences in collaboration with others. Ongoing communicative interactions guided and facilitated in the context of collaborative problem-solving are highly relevant to operationalising this principle. Doolittle (1995) also notes that to talk to oneself or think out aloud is a useful tool that is used by children and adults alike to solve problems. It can be part of rehearsal as well. One primary purpose of talking aloud is to guide students towards thinking individually. Vygotsky (1987) also recognised the importance of this process as the basis of learning; and that expressing thoughts aloud with others eventually becomes internalized as part of people’s repertoire of problem-solving strategies (Doolittle, 1995). The use of language is key to helping people to be strategic, rather than just impulsive in their responses, and so assists their approach to complex problems by encouraging thinking about what is best to say, as well as controlling behaviour. Thus, speaking to one’s self can facilitate the internalisation of knowledge and its organization as well as problem-solving. Thus, this principle applied to the way students were given time to participate and were guided to think about the experimental activity and the manipulation of the variables involved and both their written tasks and interactive communications. This ultimately led to them problem-solving. In this research, the leaders in the activity encouraged students to self-talk through the online conference tool before discussing the results with peers. While the students engaged in the Voltage Divider Experiment, this allowed natural talk and thinking in relation to the tasks. Moreover, both time allowance and task and learning experience structure were important to the collaborative activity.

3.1.5 Provide opportunities for verbal interactions - Principle Five

Language represents the channel through which ideas and behaviour patterns become internalised so it is not surprising that Doolittle (1995) emphasises that classrooms that are silent lack opportunity for conversation or exchange of ideas (Doolittle, 1995). Thus, as with Principle Four, using language to dialogue allows for the co-construction of knowledge with peers and involves cognitive and metacognitive skills. Verbal interactions involve patterns of behaviour, and as Doolittle notes, facilitate the thinking and restructuring of mental functions. Thus, collaborative learning involves such verbal interactions in a meaningful way in relation to how the task and activities are designed for students’ engagement. According to Marden and Herrington (2011), social interaction and collaborative learning among learners are essential components in assisting learners in advancing through their ZPD. Thus, it can be appreciated that the Voltage Divider Experiment is specifically designed to promote verbal interactions between both all involved. The design of questions and facilitation of the demonstration and discussion of the results were all vital to ensure this principle could be met. Also, the leader was able to observe the level and nature of interaction in the RALs to gain insights into the level of engagement.

3.1.6 Closely monitor student progress to avoid assigning tasks that are not within a student's zone of proximal development - Principle Six

The close monitoring of student collaboration is designed to ensure that every student faces the same level of challenge, and that each student can learn the assigned material. Just because students work in collaborative groups does not guarantee they are relating to the content, which has been designed for their learning (Doolittle, 1995). Teachers need to be careful in defining the learning tasks since they need to be in keeping with their Zones of Proximal Development (Vygotsky, 1987), which means the designer needs to have relevant data on students knowledge and skills.

In the present task, the leader was required to closely monitor students in collaborative groups for two main reasons. First, there was a need to ensure that each student was sufficiently challenged; and second, the intended material needed to be determined for each student’s learning needs. Thus, the students’ tasks were designed to sequence from easy to more difficult and to ascertain what students knew (formative assessment) and then facilitate them asking for assistance from other students to help construct their knowledge (ZDP). This was because there were different education levels; and any tasks that were either below or above a student’s level would be less faciliatory regarding collaboration. In this research, for example, for a student who was experienced with the concept of the Voltage Divider Experiment and already knew its function, rule and could calculate the output voltage and compare the results, a different task was assigned or a different role within the activity. Also, the leader was required to monitor students to verify that they were learning the intended material. This approach was important for the design process, since just because students are working in collaborative context does not mean that they will learn the material that the activity is designed to teach. In this example of the Voltage Divider Experiment, students needed to understand how to calculate the output voltage. So, continuous formative assessment was built into the activities and verification was needed before students could move on to the next step.

3.1.7 Instruction or activities must precede a student's development - Principle Seven

Collaborative learning activities should be designed to ensure students reach new knowledge and understanding (Rivera, 1996). Thus, with regards to this principle, the task and activities were constructed in keeping with students' ZPD where students' capability evolved as they began to control the task. Collaborative learning activities, such as this one that involved the Voltage Divider Experiment, need to be designed to lead students to new knowledge and understanding. Thus, the learning activities began from below their level and moved to the upper end of each student's ZPD so that each student gradually developed their knowledge and skills to be able to master the task. The Voltage Divider Experiment was used at a time when students were acquiring the ability to think more abstractly and predict the result and achieve the expected results. Therefore, the activities were designed to increase students knowledge about the Voltage Divider rule by understanding the concepts of the theoretical aspects and calculation of the practical results.

3.1.8 Present tasks that students can perform successfully with assistance - Principle Eight

For collaborative learning to be effective and efficient, the needs of students should be continuously challenged. This means that students must often be presented with tasks that require external help or assistance for others. The student is provided with the desired form of assistance activities since the aim is not to distribute tasks beyond the current capability of students or withhold aid, as this would only lead to frustration and helplessness. However, as the students begin to understand the work that they are engaged in, assistance should be withdrawn to enable the student to take over more of the responsibility in independently carrying out the tasks. By providing activities that require the student to obtain assistance, the activity falls within the student's proximal development area and will enhance social mediation. The assistance needed in the

Voltage Divider Experiment example take several forms. The calculation works on mathematical assistance in the form of direct instructions on the amount of resistance up and calculation of the output voltage using the theoretical understanding of each circuit and the results and experiments as they relate to the calculation. For the experimental voltage divider, assistance in the form of providing a standard level of voltage output and results that other students organise for the registration of experimental trials is to be provided.

3.1.9 Provide sufficient support to enable the student to perform challenging tasks successfully, and then gradually withdraw support as the student becomes more skilled - Principle Nine

As mentioned earlier in Principle 8, students must encounter activities that require some kind of assistance; however, for learning to take place, this assistance must be available. The student should be given the required form of assistance in activities; however, as learning accrues, less aid is necessary. Tasks should not be beyond the current capability of the student as it may lead to frustration (Doolittle, 1995). In addition, as the students begin to understand the work that they are engaged in, assistance should be withdrawn so that the student may take over the responsibility for implementing important tasks independently. Assigning tasks beyond the student's current ability, and not assisting, only leads to frustration and despair. Besides, as students gain confidence in learning the task, gradual withdrawal of assistance occurs and allows the student to independently carry out the task. Furthermore, the leader involved in the Voltage Divider Experiment can assist in the form of knowledge and organizing materials for the activity, as well as providing assistance when needed or when a team member needs to repeat the same task correctly or is having difficulty with a task; Support can then be gradually withdrawn to allow the student to take responsibly and ultimately understand the task.

3.1.10 Students must be given the opportunity to demonstrate learning, independent of others - Principle Ten

The final goal of a collaborative learning activity is for each group member to gain the necessary understanding to implement every aspect of the activities and skills independently. For students to be able to have confidence in actively carry out activities alone, they should be given the opportunity to attempt this activity independently (Eison, 2010). A student should undertake to complete this task independently, and a method for assessment formulated to determine whether the student has mastered the task at hand. Giving a student a task to complete independently also provides a method of assessment for the leader to determine if the student has mastered the task at hand. Following the Voltage Divider Experiment, each student may then be asked to determine the calculation and measure the output voltage and compare the result independently.

3.1.11 Construct activities that are designed to stimulate both behavioural changes and meet cognitive changes - Principle Eleven

Activities should be offered in an organised structure conducive to the development of students in displaying certain behaviours, as well as developing the capacity to plan, and control behaviour (Osberg, 1997). Students should be encouraged to set up their mental representations of tasks learned. This constructivist method leads to better development, retrieval and transfer of knowledge. For this construction process to be completed, the student must build not only knowledge itself (and its relationship to other cognitive activities), but also the necessary capability to use that knowledge effectively. In the case of Voltage Divider Experiment, students have an understanding of the nature of the role of divisive voltage and theoretical concepts and can calculate different types of summation resistors and calculate the total resistance; and determine how to calculate the output voltage and apply this concept of Kirchhoff's law and Ohm's law for various tasks in various fields. Table 3.1 summarises the 11 principles and how they are used in this study.

Table 3.1

Doolittle Eleven Principles of Learning Experience Design and Summary of How they are Used in this Study

Doolittle (1995) principles	**Summery as used in this study**
Teach using whole and authentic activities.	As a whole and as an authentic cooperative learning activity learning through the Voltage Divider activity provided a way of exploring Kirchhoff's law and Ohm's law and how they work in practice in the real world.
Create a ‘need’ for what is to be learned.	Once students understand the need for Kirchhoff's law and Ohm's law in the Voltage Divider activities it should have been

Doolittle (1995) principles	Summery as used in this study
	easier to motivate them to understand the need for the calculations and measures and comparison of measurement values.
Create classroom exercises that require social interaction with peers, parents, teachers, or professionals.	Each student was required to interact socially in both the calculating and the measurement actions with their peers and the leader in a small group of 3 or 4. This social interaction was designed to allow them to exchange ideas and experience new behaviours and, ultimately, through the collaborative dialogue express themselves and absorb the new ideas.
Encourage self-talk or egocentric speech.	The design of the Voltage Divider Experiment learning activities aimed to stimulate participants' interactive talk and at the same time, it involved them in problem-solving through the manipulation of the variables that should in turn have provided them with the opportunity to think and employ self-talk or egocentric speech.
Provide opportunities for verbal Interactions.	The task and learning experiences using the Voltage Divider activity were specifically designed to promote verbal interactions between both the leader and team members and between the team members.
Instruction or activities must precede a student's development.	In this study, students should have had some prior knowledge of the theories that underpin the Voltage Divider e.g. Kirchhoff's law and Ohm's law, but for those who were less familiar did not take on the leader role so they were able to be free to participate in the procedures to experiment, and ask questions to ensure they fully grasped the whole activity concept and though formative assessment assistance and final verification took place.
Present tasks that students can perform successfully only with the assistance	The research planned to construct a task that would be at the upper end of each student's zone of proximal development so that the student needed to develop in order to completely master it. The Voltage Divided activity prompted the team members' ability to think abstractly and predict results on the basis of them experimenting through the manipulation of the variables involved. The role of the leader included the provision of assistance.
Provide sufficient support to enable the student to perform challenging tasks successfully, and then gradually withdraw support as the student becomes more skilled.	In this research, the assistance provided for the Voltage Divider activity took several forms. This was managed through the task design, which was structured through the enabling of the collaborative approach that involved the role of leader. For the theoretical aspect when working on the mathematical calculations, assistance was in the form of direct instruction concerning the role of sample space, outcomes, and trials as they relate to calculating output voltage cross resistors relevant to Kirchhoff's Law and Ohm's Law. For the experimental practical processes, involving the identification and manipulation of the variables, assistance was available during the sessions from the leader and drew on the collaborative approach that encouraged participants' questioning and discussion. For the technology considerations, instructions were provided to enable the participants to set up their computers to access the RAL.
Students must be given the opportunity to demonstrate learning independent of others.	While the task design allowed the leader to provide assistance in the form of knowledge and organizational materials and time management for the Voltage Divider activities, the instructions to the leader gave a sequential approach to encourage participants' ultimate independent demonstration of having met the learning objective.

Doolittle (1995) principles	Summery as used in this study
Construct activities that are designed to stimulate both behavioural changes and cognitive/metacognitive changes.	The task was designed to lead participants through a set of instructions that were sequenced to draw out the required understanding through the role of the leader and the roles of the learner to enable each participant to demonstrate their understanding. Giving each team member turns to complete independently also provided a method of formative assessment and then summative assessment for the leader to determine if participants had mastered the task at hand.
Closely monitor student progress in order to avoid assigning tasks that are not within a student's zone of proximal development	This is closely related to principles 6, 7 and 8 for which the design of the Voltage Divider activity learning task and participants' roles and responsibilities, including the instructions for the leader facilitated the ability to closely monitor participants' progress. It was ensured that the team members had some understanding of the nature of Kirchhoff's Law and Ohm's Law, and to be able to calculate various types of equations.

3.2 The LabVIEW Task Design (Voltage Divider Experiment)

LabVIEW software was used to create the task design, that is, the Voltage Divider Experiment: "LabVIEW is systems engineering software for applications that require test, measurement, and control with rapid access to hardware and data insights" (National Instruments, 2017). It is essentially an environment enabling programming in G, where G-code stands for 'geometric code', which is a graphical programming language. This was created by National Instruments (2017) and was initially developed to communicate through a General-Purpose Interface Bus (GPIB), but this has been improved in recent times. Currently, G can be used for automated testing applications, general data acquisition and design, including programming (Elliott, Vijayakumar, Zink, & Hansen, 2007).

This technology provides a variety of other facilities and activities that include debugging, automated multithreading, application student interfaces, hardware management, and interfaces for system design (National Instruments, 2017). It has the ability to act as a portal for such facilities, bringing them together under a single element that is easy to manage. LabVIEW provides a generally low-cost solution for the design and support of laboratory instrumentation compared to traditional equivalent software because it is seen as more student-friendly (Basher & Isa, 2006).

3.2.1 Block diagram

Since the research activity and task design involves students understanding the laboratory theory involved as well as the instrumentation, there is a need to explain the details through the use of figures and images taken from the LabVIEW program. Figure 3.1 shows the block diagram, displaying the graphical source code of a sample on the Voltage Divider Experiment see Figure 3.1 LabVIEW program (National Instruments, 2017). The concept of a Block Diagram is at the core of use. The block diagram, as shown in Figure 3.1, contains the graphical source code of a LabVIEW program. The block diagram includes graphical source code from the LabVIEW program. The concept of a block diagram is to separate the graphical source code from the user interface logically and simply. It also includes terminals, subVIs, functions, constants, structures, and wires that transfer data among other block diagram objects (National Instruments, 2017). From a design perspective, there is a need to understand that the front panel objects appear as terminals on the Block Diagram. These terminals reflect the changes made to their corresponding front panel objects and vice versa when the instrumentation is in use. For example, for the Voltage Divider Experiment, when a student grabs a resistor it appears on the block diagram, as shown in Figure 3.1, below R1, R2 and R3; and it appears on the front window indicator for manipulation, as well as the block diagram for designing the activity (coding) and the front windows for manipulating.

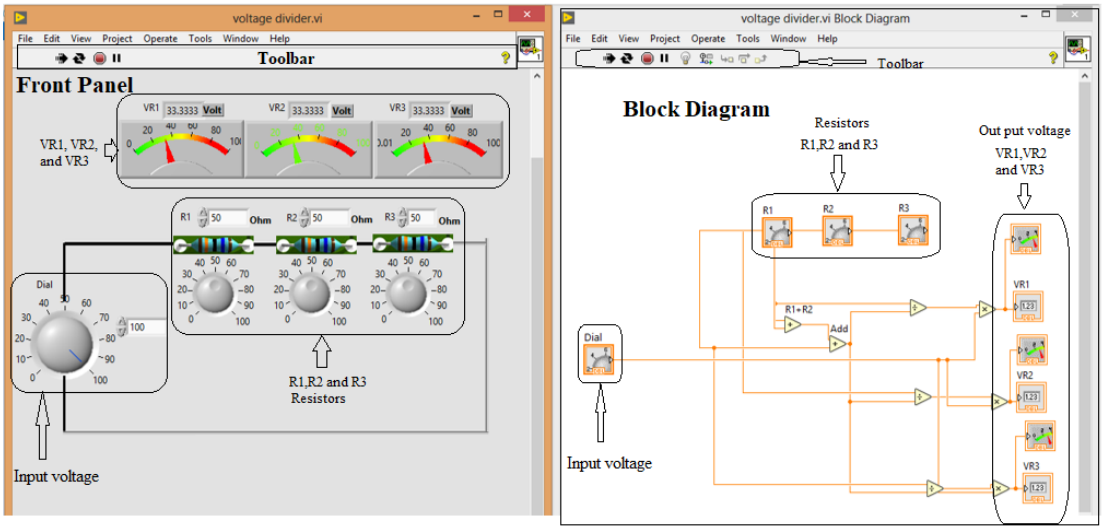


Figure 3.1: Front and block diagram details

As shown in Figure 3.1, when you create or open a new Virtual Instrument (VI), the front panel opens automatically. To display the Block Diagram, the student must choose "Window »Show Block Diagram" from the menu bar. Additionally, the student can toggle between the Block Diagram and the front panel by pressing <Ctrl-E> (see National Instruments, 2017).

The objects contained in the Block Diagram objects include terminals, subVIs, functions, constants, structures, and wires that transfer data among other objects shown in the diagram (National Instruments, 2017).

Importantly, for the present research activity design, LabVIEW tools can be used to create, modify or debug a VI. A tool is a special operating mode of the mouse pointer, so the operating mode of the pointer corresponds to the icon of the tool selected. Also, LabVIEW chooses which tool to select based on the current location of the mouse. Moreover, it can be physically chosen by selecting it on the 'Tools Palette' (from the menu bar, select 'View » Tools Palette') as shown in Figure 3.2. It may be chosen as the desired tool, which remains selected until another tool has been chosen from the Tool palette. The details as noted above and software use is very well supported in terms of manuals, specification and online training (National Instruments, 2017).

Figure 3.2**:** Tool palette

The ability to drag and drop items from the function's palette into the Block Diagram is an advantage of the program. The function palette is shown in Figure 3.2. This palette automatically appears when the student right-clicks anywhere in a space on the Block Diagram. As shown in Figure 3.2, choices include such functions as Structures, Arrays, Timing, and the ability to create sub-virtual instruments (subVIs) such as when to add SubVIs has been created to use inside another VI or it can be accessed on the Functions palette. Any VI has the potential to be used as a sub VI. Just double-click a sub VI that is on the block diagram, its front panel window appears, and one can access its block diagram to build sub-VI (National Instruments, 2017).

3.2.2 Front panel window

The program involves a ‘Front Panel Window’, such that when the student opens a VI it is shown on the front panel. In addition, functions such as the Graphical Student Interface (GUI) can be seen (see Figure 3.1). The student is able to locate the source code that ‘runs’ from the front panel on the Block Diagram (National Instruments, 2017). The front panel window also contains a toolbar, as shown in Figure 3.1, across the top and a control palette that can easily be accessed by right-clicking anywhere on the screen. These choices are illustrated in Figure 3.1. After opening the Control palette, it can be used to drag and drop controls and indicators on the front panel. In addition, as the student switches windows, each one has its toolbar. For instance, from the front panel window toolbar buttons, the student can run and edit their VI (National Instruments, 2017).

3.2.3 Activity description

This section explains how participants will learn about the Voltage Divider Experiment and the series resistance in the circuits through their participation in the RAL. Since the voltage divider is a circuit that produces an output voltage to the input voltage according to the crossing resistance, it splits the input voltage among its resistors. The participants discover this through both simulation and hands-on work using the LabVIEW software, which emulates the real experience. The prerequisite skills that the participants required to participate in the Voltage Divider Experiment are:

- Basic proficiency in using LabVIEW software including manipulating the variable resistor and input voltage (can use the LabVIEW and controlling the number of resistors and increase and decrease the input voltage).
- Knowledge of electronic engineering such as Voltage Divider Experiment rule (e.g. information about the theory and Ohm's Law).
- Understanding of the Voltage Divider Experiment components and their behaviours (such as resistance voltmeters and how they work).

In the present research, the participants ascertained how to undertake the activity during collaborative learning through experimenting. It is; also expected that as electronic engineering participants, they came with a basic understanding of the skills required.

3.2.4 Activity design of the Voltage Divider Experiment

When considering the activity design for the Voltage Divider Experiment, it is important to understand the Voltage Divider's purpose, in that it applies to any part of a circuit in which the voltage appears across two or more series-connected elements (National Instruments, 2017). The voltage divides across each item proportionally based on the resistance of the component. Thus, voltage dividers are fundamental to use as a circuit analysis technique. It has practical application in its ability to produce specific voltage levels from a system's power supply. Thus, the key purpose of using voltage dividers is to change input voltages into smaller output voltages of specified values. A practical example of an electrical and electronic engineer needing to apply this voltage is to use a single voltage source and the voltage divider to solve the cost required for a large circuit size. Most electrical and electronic equipment needs various levels of voltages throughout their circuits. Three individual power sources can provide these electrical current requirements. But with the voltage Divider Experiment, one circuit can fulfil all of those requirements as they are made up of at least two or more resistors in series with the voltage power supply (National Instruments, 2017). Voltage is dropped across the first resistor, leaving a lessened voltage (equal to the voltage drop across the second resistor) that is output from the circuit.

3.2.5 The requirement of the activity

As a condition of the research activity design the participants were required to calculate the various resistor amount and output voltage after divider to smaller amount according to the given resistances, and experimentally observe the voltage drops in Voltage Divider Experiment. The activity also was designed to allow participants to control their interface using a LabVIEW web page. The design provides support to participants to calculate and find voltages across resistors and then use the circuit to determine an unknown resistance. Again, this task at the engineering practice level prepares participants to be able to understand the basic concepts of voltage, current and resistance; and learn about various resistor combinations. These basics of all important topics of circuit laws are the foundation of the analysis of circuits. The next step is to apply the concept to make the voltage Divider Experiment. The Ohm's law help analyse branching and division of voltages in electronic circuits. The circuit voltage law is called Kirchhoff's Voltage Law. This law states that in a closed circuit, the voltage provided by a supply (battery) is equal to the sum of voltages across the resistors in the circuit. Consider the following circuit consisting of a battery of voltage V and three resistors. The KVL indicates V = V1 + V2 + V3. Reinforcement ensued by doing this activity in different ways. For example, the resistor on this activity was a series connection—they can try it which are further described in Section 3.2.7. On completion of this activity, they can understand the well-known and principal electronic law, i.e. Ohm's Law.

3.2.6 Learning objectives

The learning objectives for the research the activity design was drawn from National Instruments (2017). It notes that after completing the Voltage Divider Experiment participants will be able to:

- Discuss the purpose of voltage dividers.
- Calculate the expected voltage output of various voltage dividers across each resistor.
- Design and implement an appropriate Voltage Divider Experiment, given the desired specifications and component.
- Calculate the expected voltage output across resistors; verify using LabVIEW interface (front panel).
- Discuss the purpose of voltage dividers and resistance; provide example scenarios of when they would be used.
- Calculate the expected voltage output of various voltage dividers; verify using instrumentation.

- Calculate the expected voltage output across the resistance of various resistance configurations; verify using instrumentation.
- Design and implement an equivalent resistance and measure the resistance across the circuit.
- Measure the voltages of a multi-resistor voltage divider.
- Calculate the voltages using the voltage divider equation.
- Compare the calculated and laboratory-measured values.
- Use data from simulation and circuit-building.
- Report the results to the activity leader.

3.2.7 The theory underpinning the Voltage Divider Rule

Central to participants' learning underpinning the Voltage Divider is the Voltage Divider Rule (VDR). This rule states that "the voltage across an element or a series combination of items in a series circuit is equal to the resistance of the element or series combination of items divided by the total resistance of the series circuit and multiplied by the full impressed voltage". This voltage divider circuit is shown in Figure 3.3.

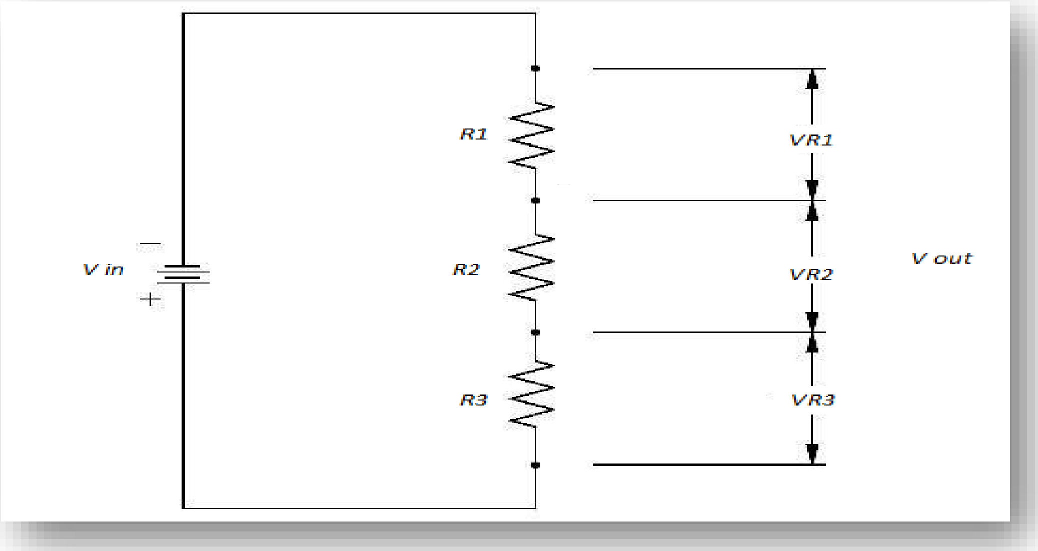


Figure 3.3: Voltage divider circuit

Figure 3.3 demonstrates the forward characteristics of resistors connected in series with an input voltage supply. The subsequent image, Figure 3.4, shows the Front Panel and Block Diagram of the LabVIEW VI, respectively. Through the front panel, the participants enter the range of resistors (minimum and maximum) in several steps. These resistor amounts are used to compute the actual out voltage that is applied to the load circuit in steps. The Block Diagram, which is the source code of the VI, first checks if the maximum and minimum registers and voltage input entered by the student exceeds the permissible amount (0:100V).

The Front Panel of the application contains two sections. The first, the Function Generator, is displayed on the left, and Potentiometer of Resistors is displayed: the potentiometer is a resistor with a movable element (wiper) as the wiper moves the resistance between the wiper and terminal changes, as shown in Figure 3.4. The function generator enables the student to generate input DC voltage.

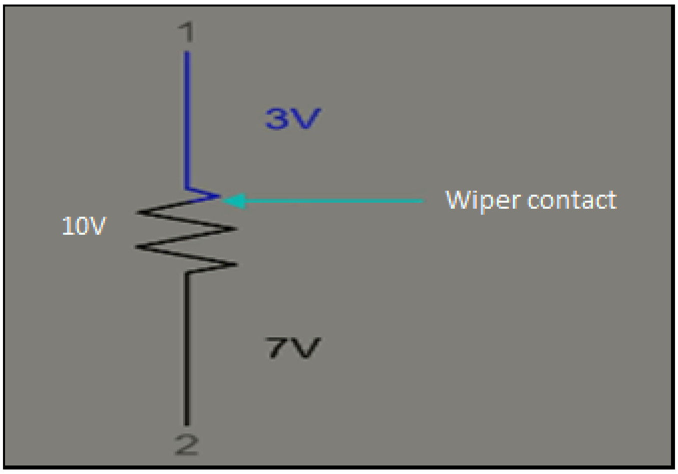


Figure 3.4: Potentiometer

Figure 3.5 indicates the principle of the voltage divider circuit code, where:

V out = Output voltage. *VR1*=voltage across *Resistor 1*, *VR2*= voltage across *Resistor 2, VR3*= voltage across *Resistor 3, V in* = Input voltage, *R1* and *R2* = Resistor values.

It shows the voltage divider code on the LabVIEW block diagram window.

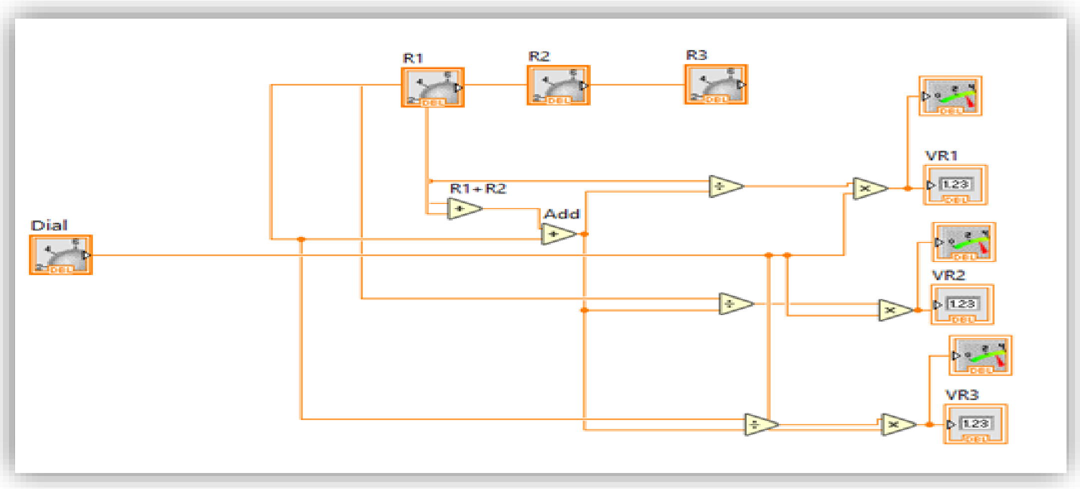


Figure 3.5: Voltage divider codes on LabVIEW

In the voltage divider circuit displayed in Figure 3.5, data have been entered in the front panel controls R1; R2 and R3 of the Block Diagram through their respective control terminals. The data are then entered in the addition, multiplication and division functions. When these calculations are completed, they produce new data values that flow to the indicator terminals where they update the front panel indicators, in keeping with the following notations:

(*R1*+*R2*+*R3*) and (*V in # R2*) and division

($V_{out} = V_{R2} = \frac{V_{in}R2}{R1+R2+R3}$).

Equation 1: Voltage divider rule: $\boldsymbol{V_{out} = V_{R2} = \frac{V_{in}R2}{R1+R2+R3}}$

Alexander (2009, p. 44) In general, if the voltage divider has *N* resistors (*R1, R2*…. *Rn*) in series with the source voltage v, the *n*th resistor (Rn) will have the voltage drop of *VRn.*

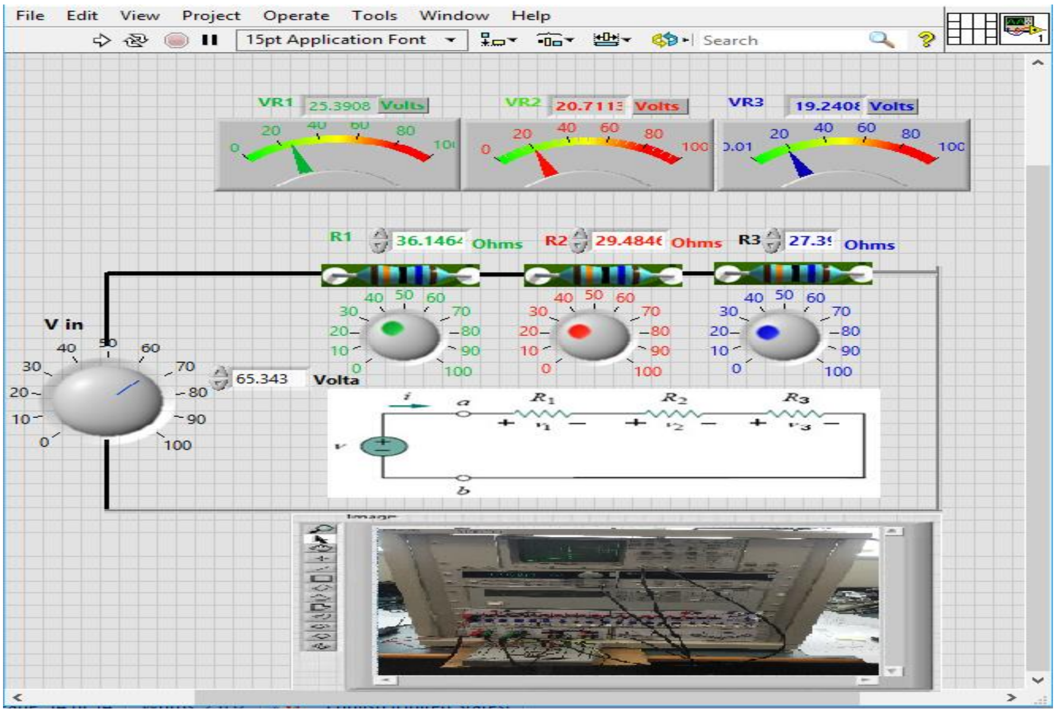
$$: \boldsymbol{V_n} = V * \frac{\boldsymbol{R2}}{\boldsymbol{R1+R2+\cdots.+Rn}}$$

A simple way to remember the voltage divider rule is that the output resistor is divided by the total circuit resistance. This fraction is multiplied by the input voltage to obtain the output voltage on each resistor (Carter & Mancini, 2017).

Dc input voltage is from 0 to 100 volts and has three resistors *R1, R2* and *R3,* and output voltage *V out* as per the Voltage Divider Rule; the *V out* equals the total input voltage *V* in into *R2* divided by *R1* plus *R2* plus *R3 (In formula V =voltage).* This result will support participants to take the input voltage drop particular resistor divided by total resistance *R1+ R2 + R3*.

To understand how to commence the research activity, participants need to have a basic idea of how the activity is coded and designed. They need also to become familiar with the LabVIEW software by opening the LabVIEW software as a new project then selecting ‘Blank VI project’. This will then open the software at the ‘new project’ space, then, to start, ‘Ctrl T’ needs to be pressed. This ensures the project window will appear in the panel and the Block Diagram panel can be used.

The first step for connecting the circuit is to connect it on LabVIEW via the resistors *R1, R2* and *R3* by right-clicking on the main front page. This takes the student to the numerical indicators and also the token knob. After turning the knob by right-clicking on it, the student needs to select ‘properties’ and check the values: maximum and minimum from 0 to 100. This will allow setting any value from 0 to 100, which can be renamed as input voltage by selecting and dragging it to wherever it is required. In addition, if there is a need to see the exact value of the output voltage participants need to go to the digital display, where the same amount is recorded to support observing the digital numerical increase and decreases on the digital display. The resistors are selected as numerical indicators from the range of properties from 0 to 1000 ohms. As a result, the digital display will show the exact value of the resistors as the voltage divider rule is applied, which means participants need to connect to addition formula and connect the resistors through the input on the LabVIEW software. In this regard, the Front Panel window appears as shown in Figure 3.6 below.



VR1 25.3908 Volts
VR2 20.711 Volts
VR3 19.240 Volts
R1 36.146 Ohms
R2 29.484 Ohms
R3 27.3 Ohms
65.343 Volta

Figure 3.6: Front panel window on local computer

The resisters are displayed in Figure 3.6, on the right side of the front panel window. This enables the student to control and manipulate the resistor from 0 to 1000 Ohm, and similarly with other resistors. The participants need to understand that *V out* equals the total input voltage and *V in* into *R2* divided by *R1* plus *R2* plus *R3*. The main purpose of the Voltage Divider Experiment is to separate the input voltage to, in this case, three outputs voltage. If the student adds all outputs voltage together, it should be equal to the input voltage. For example, when the input voltage is 9 volts and the circuit has three resistors equal in amount—3 volts— then the output for each resistor became 9 Volts, which is the same as the input voltage. In this process, the student needs to calculate the input voltage drop resistor divided by total resistance R1 R2 R3. Figure 3.1 shows the input voltage on the Front Panel and the Block Diagram and Figure 3.1 indicates the voltage across each resistor: *VR1*, *VR2*, and *VR3* on the Front Panel on the right, and Block Diagram on the left window. For a divider made up of three resistors, *R1*, *R2* and *R3* participants need to understand that the application of Ohm's Law requires (Alexander, 2009) the use of the following equation to calculate the division of voltage:

$$V_{out} = V_{R2} = \frac{V_{in}R2}{R1 + R2 + R3}$$

Where:

V out= Output voltage.

V in = Input voltage.

R1 and *R2* = Resistor values. The ratio $\frac{\boldsymbol{R2}}{\boldsymbol{R1+R2}}$ determines the scale factor.

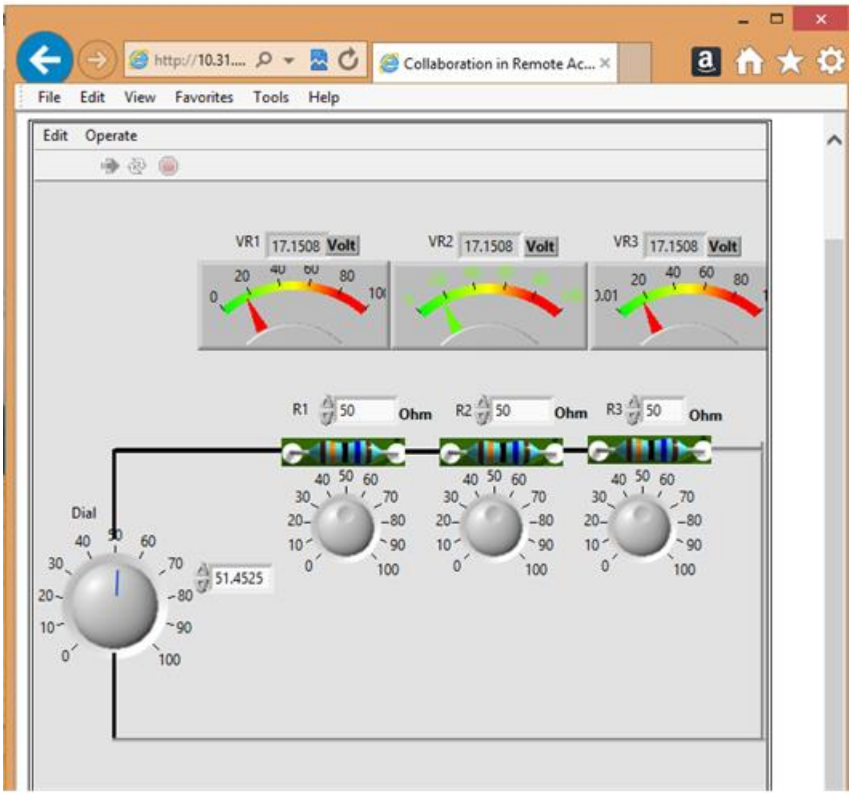
3.2.8 Applications of voltage dividers

It is important to understand the role of the Voltage Divider in the education of electrical engineering participants. The Voltage Divider has many real-world applications, as noted in Section 3.2.4, in the design of research in the RALs activity. One everyday use for voltage dividers is in sensing equipment. For instance, resistive sensors change resistance in response to external stimuli that engineers may wish to measure (Saggio, Riillo, Sbernini, & Quitadamo, 2015). Temperature is an example of an external stimulus. By creating the voltage divider with one of these components and a known resistor, the sensor resistance can be calculated based on the output voltage. Another use of voltage divider refers to logic level shifting. This involves decreasing voltages, where the voltage divider allows logic circuits to run and interact at different voltages. This has application in practice when an engineer needs to replace one of the fixed-value voltage supplies with resistors. All resistive sensors such as light sensors, temperature sensors, pressure sensors and pressure gauges, which change their resistive value as they respond to environmental changes, can be used in the network voltage divider to provide an analogue voltage output. Bipolar transistors and MOSFETs (Metal Oxide Semiconductor Field Effect Transistor) are also other common applications of the voltage divider.

In addition, voltage dividers are used on some occasions to supply a load with the voltage smaller than that supplied from the battery or the power supply. When applied for this purpose, the output voltage depends on the resistance of the load it supplies. Therefore, participants need to understand that it is generally the case for voltage dividers that a substantial R2 value in relation to R1 will yield a larger output voltage.

However, when a load resistor ‘RL’ is in parallel with R2 this causes a decrease in the total resistance in that part of the voltage divider. This, in turn, achieves a drop in the output voltage. Depending on the load resistance, RL, more current and total power may be needed from the power supply.

On the Front Panel, as seen in Figure 3.7, the layout of the LabVIEW is set up for the experiment. In the case of the present research, the team of participants can view and control the Virtual Instrument’s (VI) front panel remotely, either from within LabVIEW as the activity leader, or from within a Web browser from a link shown below. This occurs by connecting to the LabVIEW built-in Web Server. (National Instruments, 2017). When you open the Front Panel remotely as participants in this research do, the Web Server sends the Front Panel to the student, but the Block Diagram and all the subVIs remain on the server computer (or leader computer). Thus, participants can interact with the Front Panel in the same way as if the VI is running on the student’s computer, except the Block Diagram takes place on the server. This feature is also used to publish the entire Front Panel or to control the remote applications safely, efficiently and quickly.



VR1 17.1508 Volt
VR2 17.1508 Volt
VR3 17.1508 Volt
R1 50 Ohm
R2 50 Ohm
R3 50 Ohm
Dial 51.4525

Figure 3.7: View of front panel as seen remotely by the student

Thus, as noted above, LabVIEW is also a publishing tool. Participants may need to publish because the web publishing tool allows the participants to publish, view and monitor and control from the front panels remotely via the server. Similarly, participants can create an HTML document and embed static or animated images from the front panel, and they can view and control the front panel remotely via the internet (National Instruments, 2017). To do this, participants need to navigate to 'Tools»' then 'Web Publishing Tool' and open the dialogue box as shown in Figure 3.8. Please note that the Start Web Server button should be disabled if all previous steps have been followed.

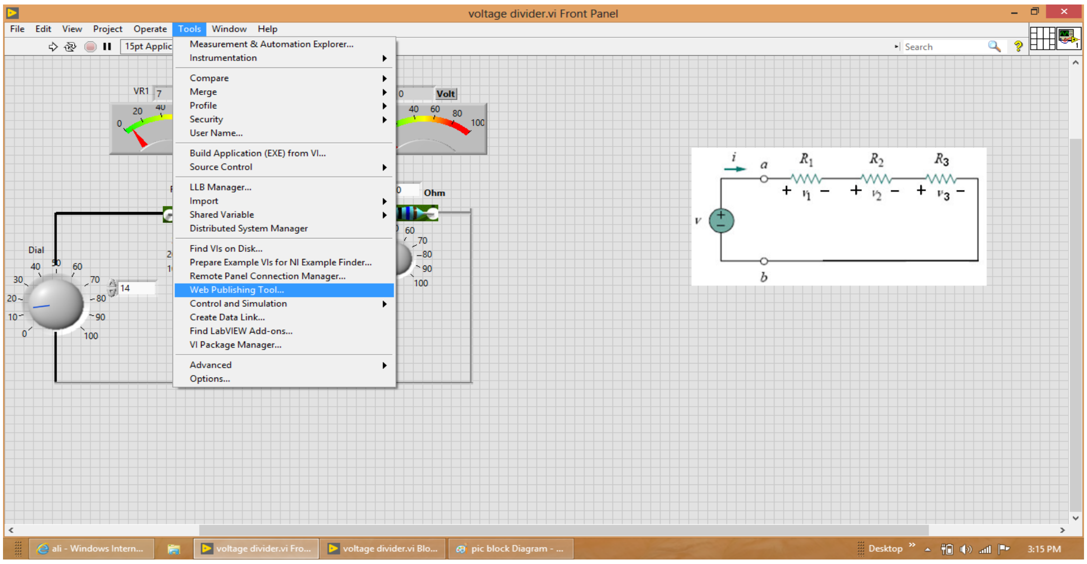
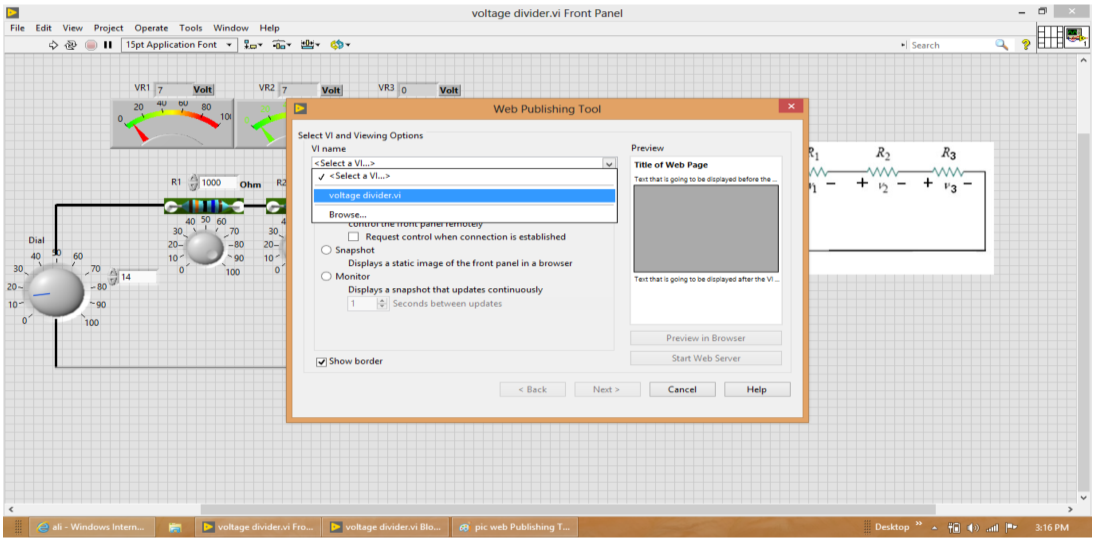


Figure 3.8: Navigating to the web publishing tool

When publishing, participants need to select the 'VI and Viewing Options' section as shown in Figure 3.9, then browse to choose the desired VI (e.g. Voltage Divider VI). It is necessary to read through the Web Publishing Tool Viewing options to ensure that the appropriate viewing mode option is selected before pressing the 'Next' button.



voltage divider.vi Front Panel

Web Publishing Tool

Select VI and Viewing Options

VI name

<Select a VI...>

✓ <Select a VI...>

voltage divider.vi

Browse...

☐ Request control when connection is established

○ Snapshot

Displays a static image of the front panel in a browser

○ Monitor

Displays a snapshot that updates continuously

1 Seconds between updates

☑ Show border

Preview

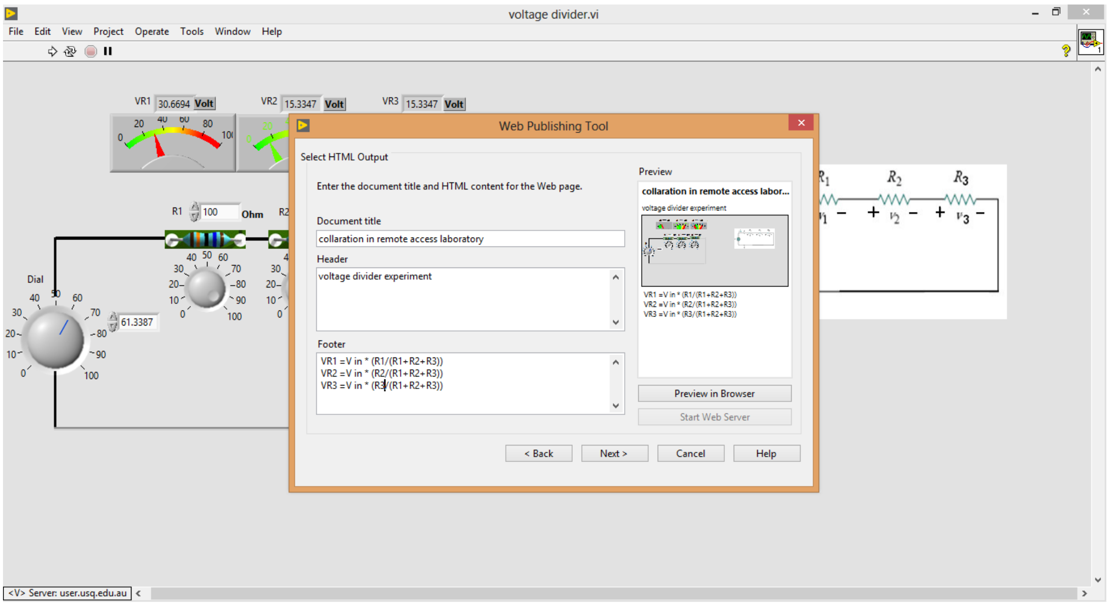
Title of Web Page

Text that is going to be displayed before the ...

Text that is going to be displayed after the VI ...

Figure 3.9: Web publishing tool selection of Voltage Divider VI

Next, it is necessary to select the HTML Output and enter the desired document title (e.g. Collaboration) in remote access laboratory, and the HTML content. A preview is available as shown in Figure 3.10. By pressing the Next button, the student moves on to being able to view the new web page.



voltage divider.vi

Web Publishing Tool

Select HTML Output

Enter the document title and HTML content for the Web page.

Document title

collaration in remote access laboratory

Header

voltage divider experiment

Footer

VR1 =V in * (R1/(R1+R2+R3))
VR2 =V in * (R2/(R1+R2+R3))
VR3 =V in * (R3/(R1+R2+R3))

Preview

collaration in remote access labor...

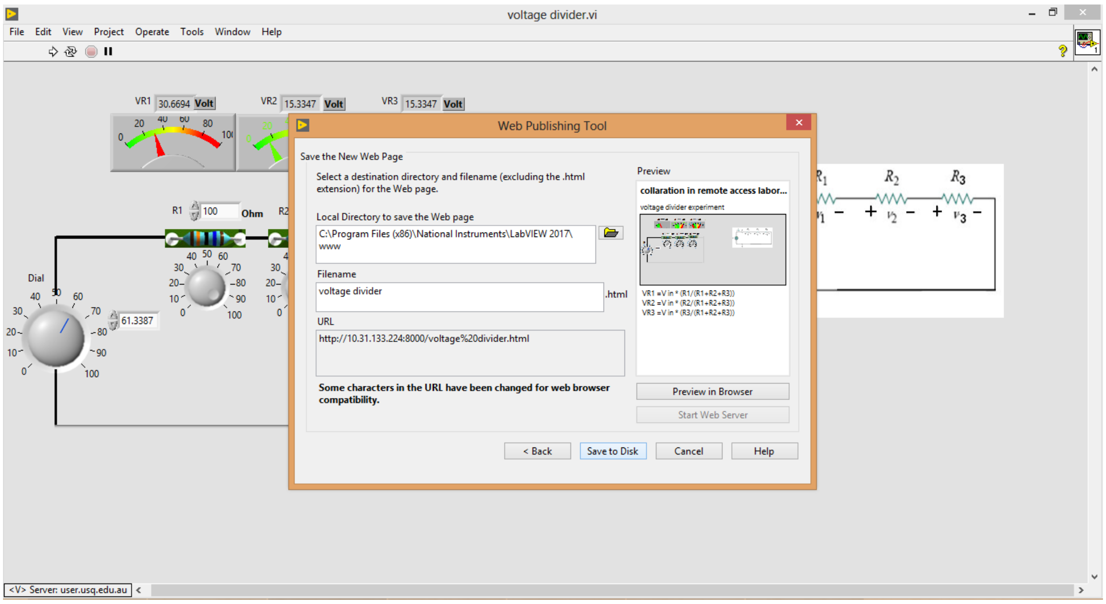
voltage divider experiment

VR1 =V in * (R1/(R1+R2+R3))
VR2 =V in * (R2/(R1+R2+R3))
VR3 =V in * (R3/(R1+R2+R3))

Figure 3.10: Web publishing tool - provision of the document title

As noted throughout this section, National Instruments (2017) provides detailed information and support for participants; and in the next step of being able to save the newly-created web page Figure 3.11 displays the 'Save the New Web Page 'option'.

The student needs to select where to save the HTML file and choose the file name and press the ‘Save to Disk’ button.



Save the New Web Page

Select a destination directory and filename (excluding the .html extension) for the Web page.

Local Directory to save the Web page: C:\Program Files (x86)\National Instruments\LabVIEW 2017\www

Filename: voltage divider.html

URL: http://10.31.133.224:8000/voltage%20divider.html

Some characters in the URL have been changed for web browser compatibility.

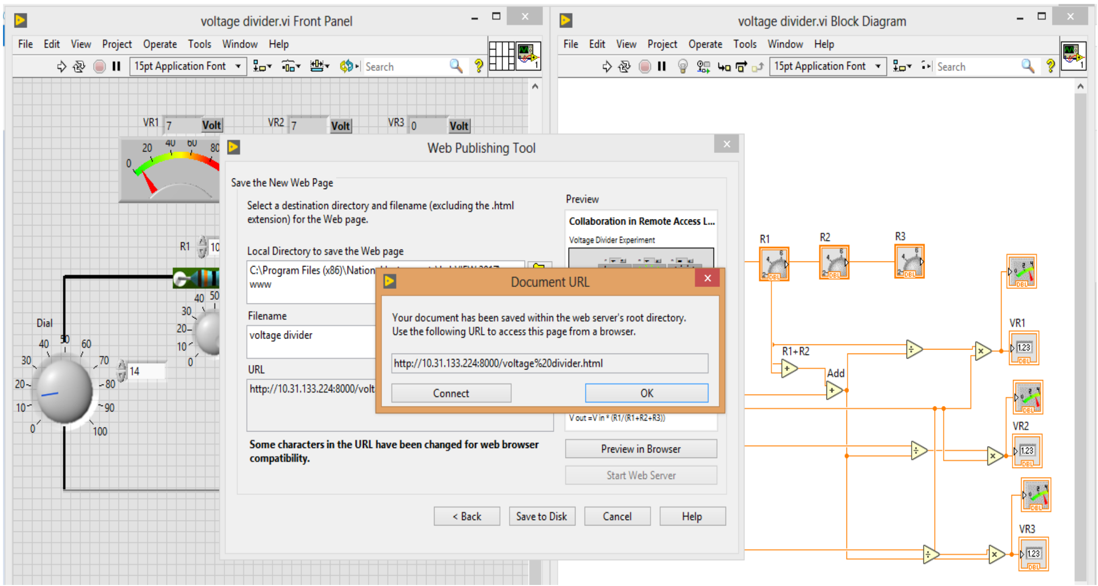
collaration in remote access labor...

voltage divider experiment

VR1 =V in * (R1/(R1+R2+R3))
VR2 =V in * (R2/(R1+R2+R3))
VR3 =V in * (R3/(R1+R2+R3))

Figure 3.11: Saving the new web page

The web page is then saved to a destination directory, as shown in Figure 3.12; and Figure 3.13 shows how the published web page appears. Then Figure 3.14 illustrates how the experiment was published on the webpage and the local computer.



Web Publishing Tool

Save the New Web Page

Select a destination directory and filename (excluding the .html extension) for the Web page.

Local Directory to save the Web page: C:\Program Files (x86)\Nation… www

Filename: voltage divider

URL: http://10.31.133.224:8000/volt…

Some characters in the URL have been changed for web browser compatibility.

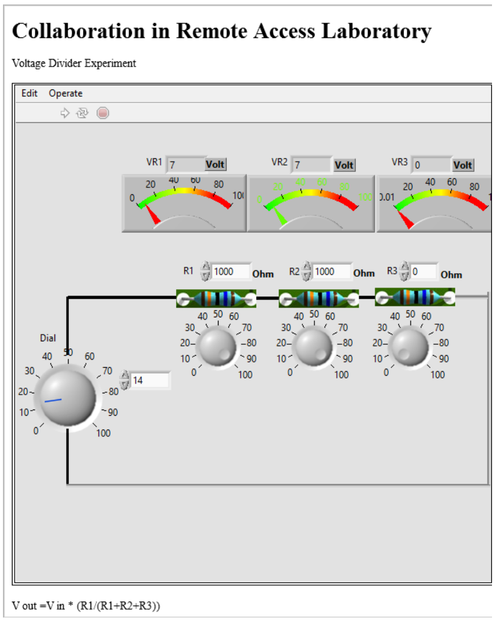
Preview: **Collaboration in Remote Access L...** Voltage Divider Experiment … V out =V in * (R1/(R1+R2+R3))

Document URL

Your document has been saved within the web server's root directory. Use the following URL to access this page from a browser.

http://10.31.133.224:8000/voltage%20divider.html

Figure 3.12: Selecting a destination directory - URL to access laboratory from browser


Collaboration in Remote Access Laboratory

Voltage Divider Experiment

V out =V in * (R1/(R1+R2+R3))

Figure 3.13: View of the published laboratory on the web browser

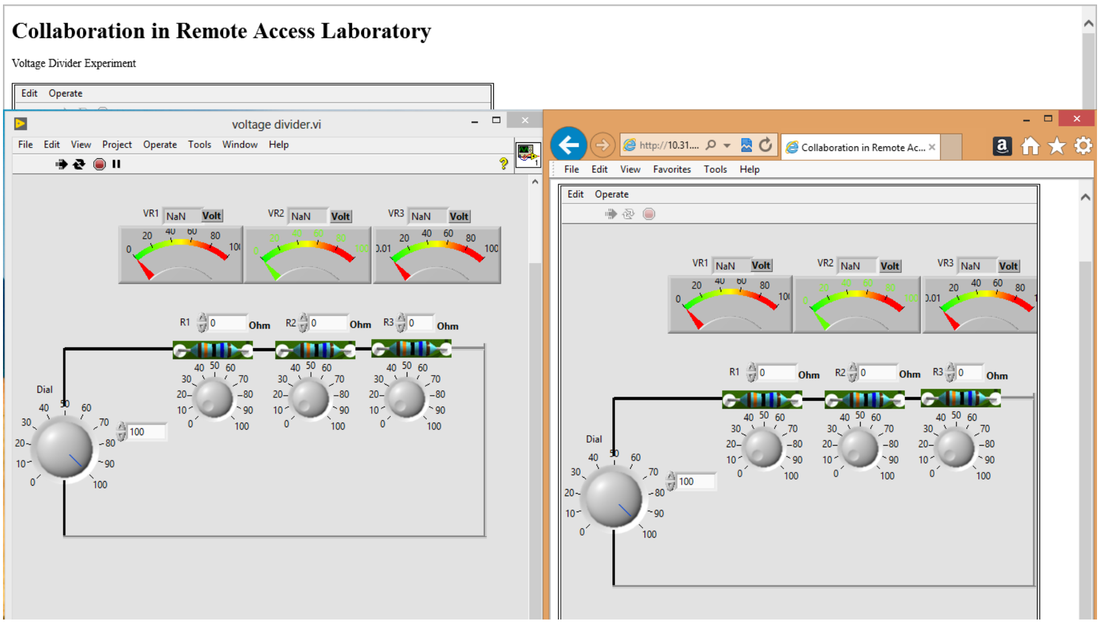


Figure 3.14: Laboratory on the internet and local computer prepared for the Voltage Divider Experiment

National Instruments (2017) advises the student to view the remote front panel using LabVIEW by first selecting ‘Operate’ then ‘Connect to Remote Panel’ to display the dialogue box. This dialogue box is used to specify the server Internet address, and the VI required viewing. The student will find that the remote VI front panel will be in observer mode, as that is the default position.

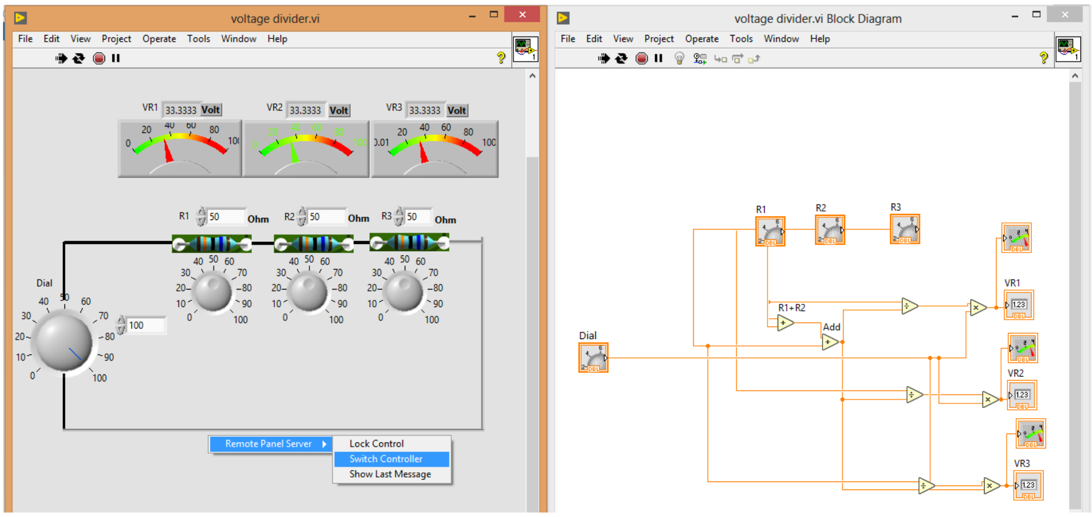


Figure 3.15: Remote front panel and block diagram windows switch controlling

From the present research activity learning experience, everyone from the student group can request control of the instrumentation by placing a checkmark in the ‘Request control’ checkbox in the ‘Connect to Remote Panel’ dialogue box, as shown in Figure 3.15. Figure 3.16 shows how a student can direct control away from server control. Then the VI (the Voltage Divider Experiment) appears on the student’s computer. Also, participants can right-click anywhere on the front panel and select ‘Request Control’ from the shortcut menu (National Instruments, 2017).

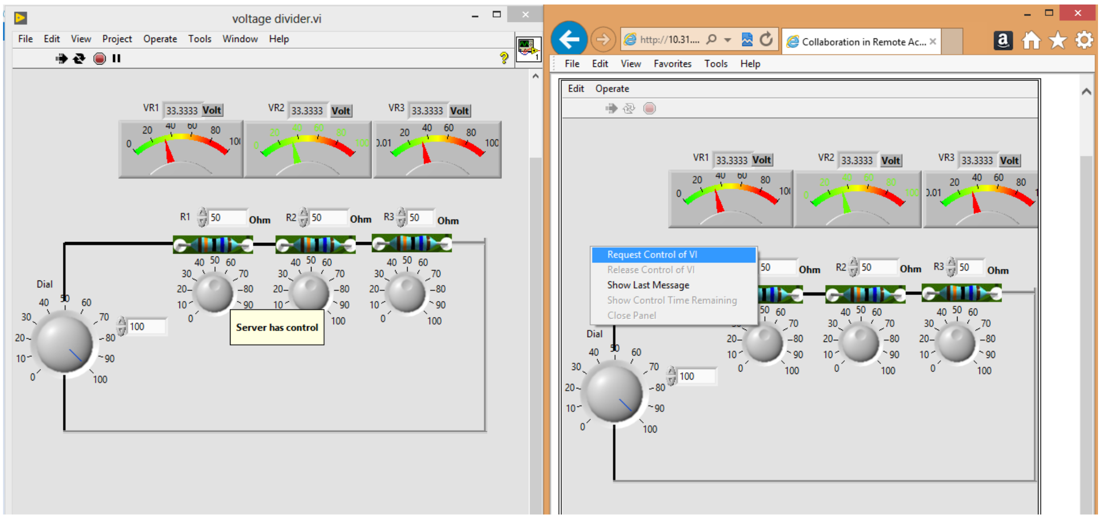
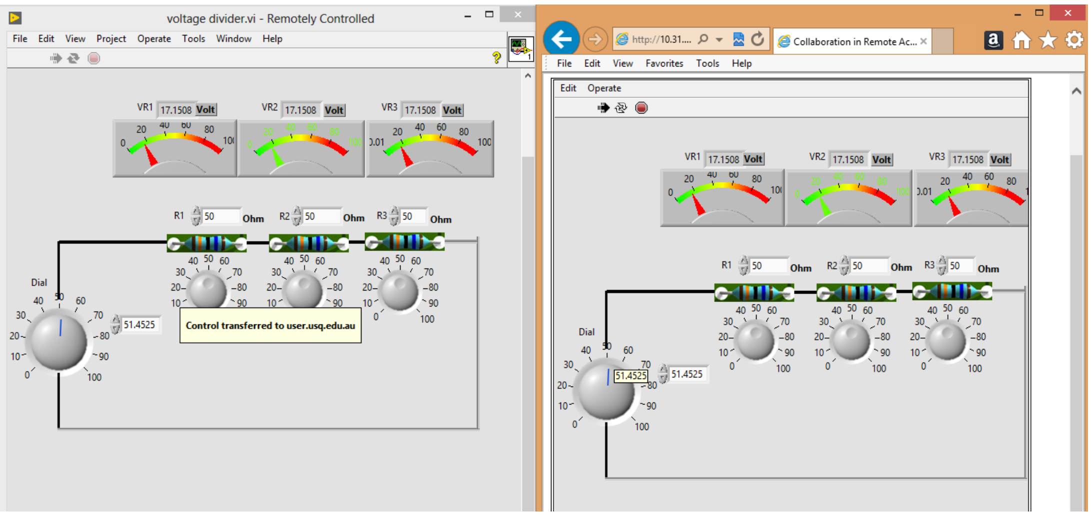


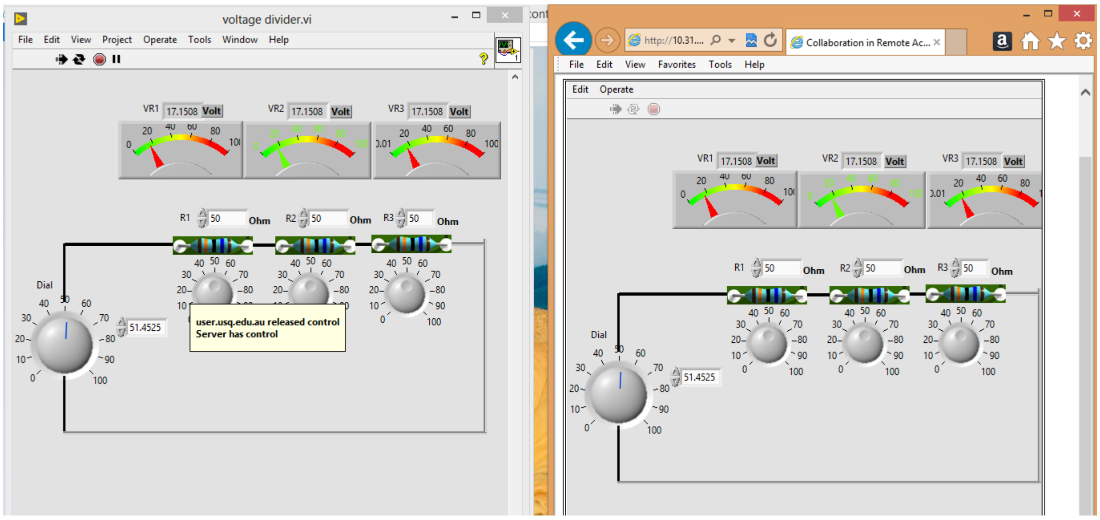
Figure 3.16: Remote front panel window - accepting a student to control

Besides, the student can access the menu by clicking the status bar at the bottom of the Front Panel window. If no other participants are in control at that time, then that student will have control of the Front Panel. If another student is in control of the VI, as displayed in Figure 3.17, and someone else attempts to take control, then the server queues that person’s request until the student in control relinquishes that domination. Figure 3.18 illustrates the switching of control between participants. However, there is also a control time limit, which eventually times out and makes control available. From the teaching perspective, only the student of the ‘server computer’ has the ability to monitor the student queue list. This is managed through the use of the ‘Tools’ button, followed by selecting the ‘Remote Panel Connection Manager’. Thus, this facility is a key component of the pedagogical approach and has implications for teaching skills since the teacher needs to be aware of the participants’ need to have control passed to them and the subsequent management of this in relation to the emergent dialogue (Contreras León & Chapetón Castro, 2017) in fostering the present research into collaborative learning in RALs.



Control transferred to user.usq.edu.au

Figure 3.17: Remote front panel window and student control and manipulation of the VI



user.usq.edu.au released control
Server has control

Figure 3.18: Remote front panel window showing switch control between participants

3.2.9 Challenges

While the use of the software and the Voltage Divider Experiment may appear straightforward, some challenges emerged. For instance, the front experimental panel in LabVIEW did not appear on most popular Internet browsers (e.g. Internet Explorer, Chrome and Firefox). Thus, participants need to be alerted to this aspect. In the present research, this was controlled by setting up the experiment using a server laptop. The laptop supported the teacher to have access and *control* of the activity and to monitor the experiment. Then participants were advised on how to gain access from anywhere via their laptops or desktop computers using the ***Internet Explorer browser*** because Google Chrome and Chrome does not support remote panels. However, access was available on Internet Explorer.

Furthermore, it was found that from the LabVIEW software, two participants can control and access the experiment (Voltage Divider Experiment); however, another team member cannot access at the same time. The researcher overcame this challenge by publishing the activity two times with a second delay. The controlling of the experiment was via two laptops because the leader’s laptop can access and control the activity with the server laptop. One of the other team members could access and control, and other team members can monitor the experiment anywhere on their laptops or desktop through the internet.

Moreover, the researcher found that from the LabVIEW software just to do web publishing two times on the run, one could control it in this case 2 participants can control and other can monitoring, then the rest of participants first for viewing mode embedded controlling (embed). Regarding time differences between controlling and monitoring with delay a second, this can make monitoring from any iPad, or smartphone—just accessing the link on Internet Explorer makes the project more powerful than before:

First time for viewing mode embedded controlling (embed) for controlling and other laptops can monitoring with delay a second this can make monitoring from any computer or smartphones just access the link on internet explorer that gives the project more powerful than before. The second time for monitoring Embedded viewing mode option results in Requested VI is not loaded into memory on the server select Snapshot or Monitor viewing mode option the page is loaded without problems.

3.3 Procedure – Task Sheet Instructions

The procedure for the collaborative learning experience was supported through the design of a Task Sheet of instructions which were provided to the group leader and each team member. The instructions are included in Appendix A, which presents the participants' task sheet; and Appendix B shows the leader task sheet. The participants were required to complete a set of sequential activities **(**which are outlined below) that included writing their observations in spaces provided for each of a total of eleven tasks. To foster the participants' exchanges they were advised to work with their colleagues in the group and as they progressed on working out their answers to check with each other to come to a consensus on their appropriateness. Figures 3.20 to 3.22 provide details of the Voltage Divider tasks showing the screenshots that convey the various aspects of the experiment. For each figure, the notation regarding the calculations the participants were required to do is documented and explained in relation to the importance of the engineering participants acquiring the requisite knowledge and skills. The link has been published on the web page for the Voltage Divider Experiment and changes depend on the local computer ID. For example, the local computer ID was (10.31.134.40:8000).

Go to webpage the circuit has been connected on LabVIEW, as shown in Figure 3.19.

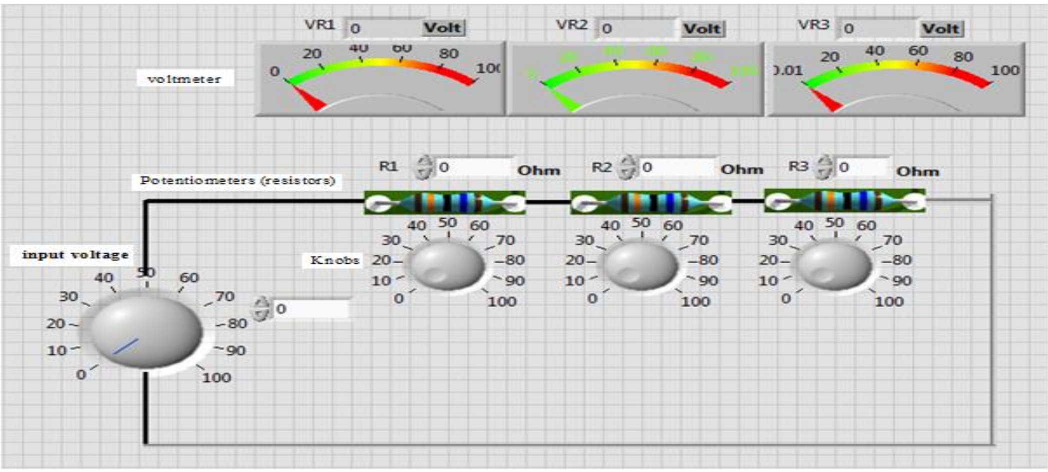


Figure 3.19: LabVIEW front page

Power with voltages between 0 *V* and 100 *V*.

Potentiometer (resistors *R1, R2*, and *R3*) has been connected.

Monitor the Volts for each resistor with voltammeter.

Ensure that there is a power-on voltage in (*V in*).

Apply the input voltage of between 0 to 100 volts from the knob to the INPUT and there will be a monitor on the knob and digital number beside the knob, as shown in Figure 3.19.

Monitor the OUTPUT with the digital voltmeter.

Check that the voltage divider works correctly by doing the following:

Ensure that the *VR1*, *VR 2* and *VR 3*) (voltage crosses resistors) are still operating.

Adjust the input voltage from the dial, as shown in Figure 3.19. You should see the voltage changes according to the input voltage and the value of resistors on the voltammeters.

Now vary the input voltage dial-up and down by hand and observe the following:

The voltage across each resistor, and the voltage difference between the three resistors varies from about 0 to the maximum voltage on each resistor.

In this case, there are 3 significant output voltages: *VR1, VR2*, and *VR3*.

A LabVIEW program has been written as explained before and can be accessed from the link provided

Sweep the Potentiometer (resisters) continuously up and down over a range which includes the entire range during which maximum and minimum voltage to each resistor is achieved.

On-screen display of the OUTPUT voltage crosses each resistor which should look like the calculation result.

Use the voltmeter as shown on the front panel to measure *VR1*, *VR2*, and *VR3* and compare them with the theory (calculations method)

On remote computer measure the voltage V input applied across the series pair of resistors.

The front panel Figure 3.19 of LabVIEW will display numerical values for each of the following parameters:

The input voltage

Resistor 1, 2 and 3

The voltage across each resistor *VR1*, *VR2*, and *VR3*

Sweep all three alternative resistors through the Knobs.

If time is still available, measure and display the *VR1*, *VR2*, *VR3, R1, R2*, and *R3*:

Sweep the Potentiometers (resistors) over to ascertain the voltage that crosses each resistor

EXAMPLE: 1. *R1* ten times *R2, and R2 equal R3*. As shown in Figure 3-20.

If time is still available, measure and display the *VR1*, *VR2*, *VR3*, *R1*, *R2*, and *R3*:

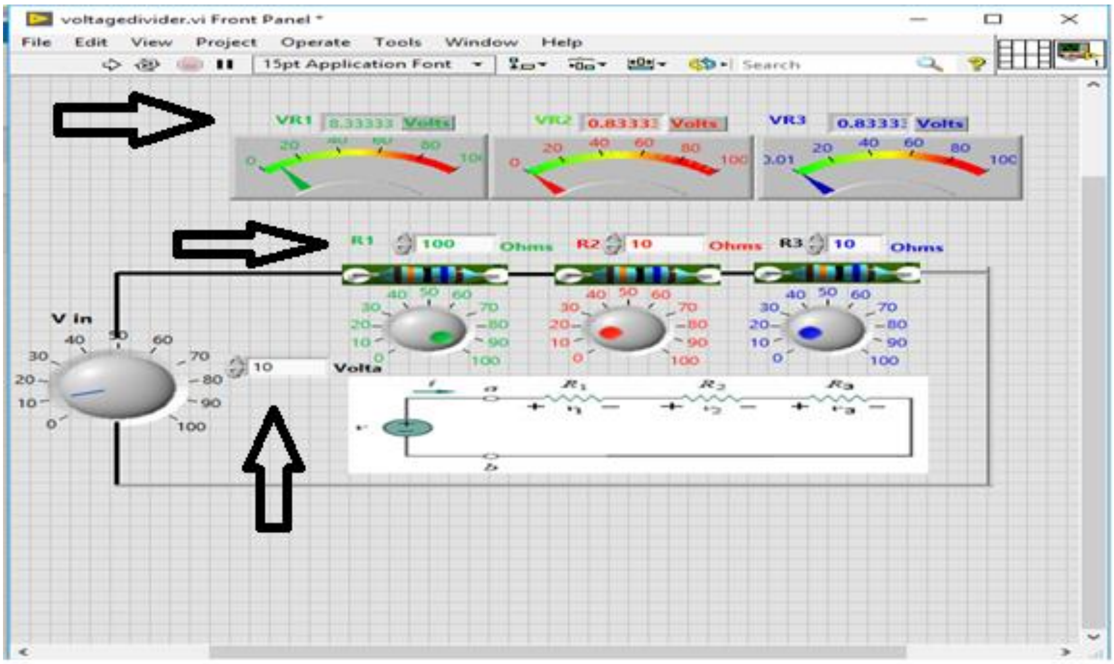
Sweep the Potentiometers (resistors) over to gain the voltage that crosses each resistor.

As the following Input voltage =10v, *R1* =100 ohm and *R2 R3* equal = *R1* divided by 10 ohms.

As seen on LabVIEW online front panel

R1=100 ohm, *R2*=*R3*=10 ohm.

V in=10 Volt,



voltagedivider.vi Front Panel *

VR1 8.33333 Volts

VR2 0.83333 Volts

VR3 0.83333 Volts

R1 100 Ohms

R2 10 Ohms

R3 10 Ohms

V in 10 Volts

Figure 3.20: Online interfaces (experimental results)

The calculation results

Based on Voltage divider rule.

The voltage across *R1*, ($V_{out} = V_{R1} = \frac{V_{in}R1}{R1+R2+R3}$)

VR1= (10*100)/ (100+10+10)

VR1=1000/120

VR1=8.33333 Volt

The voltage across *R2*, ($\boldsymbol{V_{out} = V_{R2} = \frac{V_{in}R2}{R1+R2+R3}}$)

VR2= (10*10)/ (100+10+10)

VR2=100/120

VR2=0.833333 Volt

The voltage across *R3*, ($\boldsymbol{V_{out} = V_{R3} = \frac{V_{in}R3}{R1+R2+R3}}$)

VR3= (10*10)/ (100+10+10)

VR3=100/120

VR3=0.833333 Volt

It was found that the experimental result (as seen in Figure 3.20) matched the calculation result—that means the experiment worked correctly and the voltage divider also worked well because it divides *Vin* 10 volts as follows:

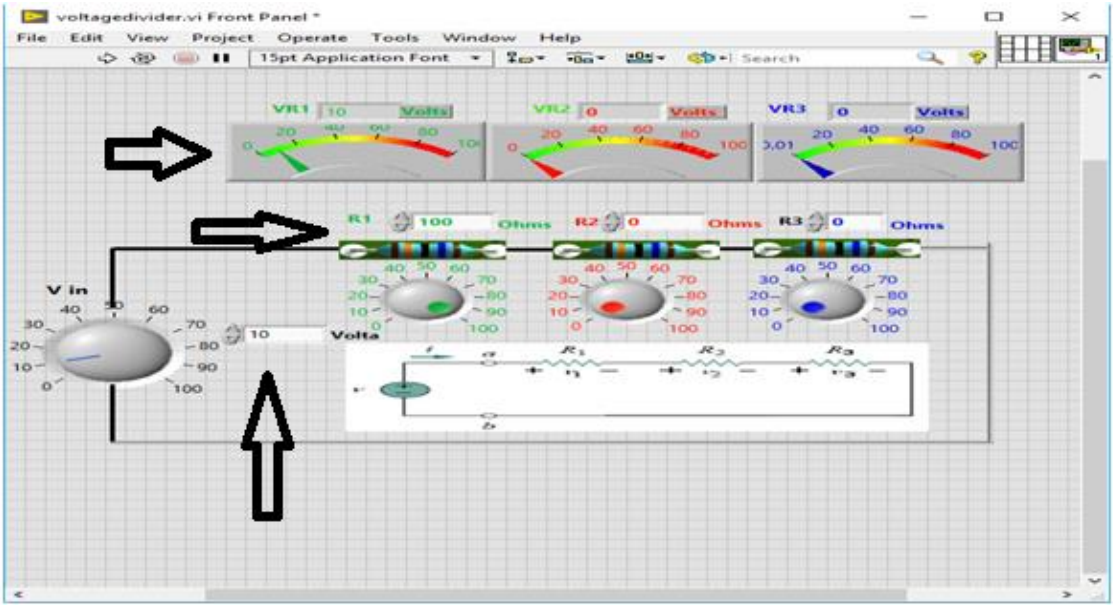
R1= 100 Ohm is 10-time *R2* = *R3*= 10 Ohm

VR1=8.33333 Volts is 10 times *VR2* and *VR3*=0.833333 Volts

The voltage divider is a simple circuit which makes the voltage into a smaller one. Using only two or more series resistors and input voltage, we can create output voltage which is part of the input and is in direct proportion to the resistors' values.

EXAMPLE: 2. *R1* =100 ohm and *R2, R3* equal zero.

Also, *R1* the 100-ohm value *R2, R3* equals zero, as seen in Figure 3.21.



VR1 10 Volts

VR2 0 Volts

VR3 0 Volts

R1 100 Ohms

R2 0 Ohms

R3 0 Ohms

V in 10 Volts

Figure 3.21: Online interfaces (experimental results)

As can be seen in Figure 3.21, when *R2* and *R3* equal Zero, the input voltage equals *VR1*.

Based on the calculation:

The voltage across *R1*, ($V_{out} = V_{R1} = \frac{V_{in}R1}{R1+R2+R3}$)

VR1= (10*100)/ (100+0+0)

VR1=1000/100

VR1=10 Volts is equal as *Vin*

And *VR2*, *VR3* equal Zero

Because *R2* and *R3* are the same value that means they are the same across the voltage;

Because *R2*, *R3* have the same value that means the same crossing voltage.

The voltage across *R1*, ($V_{out} = V_{R1} = \frac{V_{in}R1}{R1+R2+R3}$)

VR2, *VR3*= (10*0)/ (100+0+0)

VR2 =*VR3*=0/100=0

EXAMPLE: 3. *R1* 10 ohm, *R2*, *R3* double time *R1*.

R1 10 ohm, *R2, R3* double-time *R1* as seen in Figure 3.22.

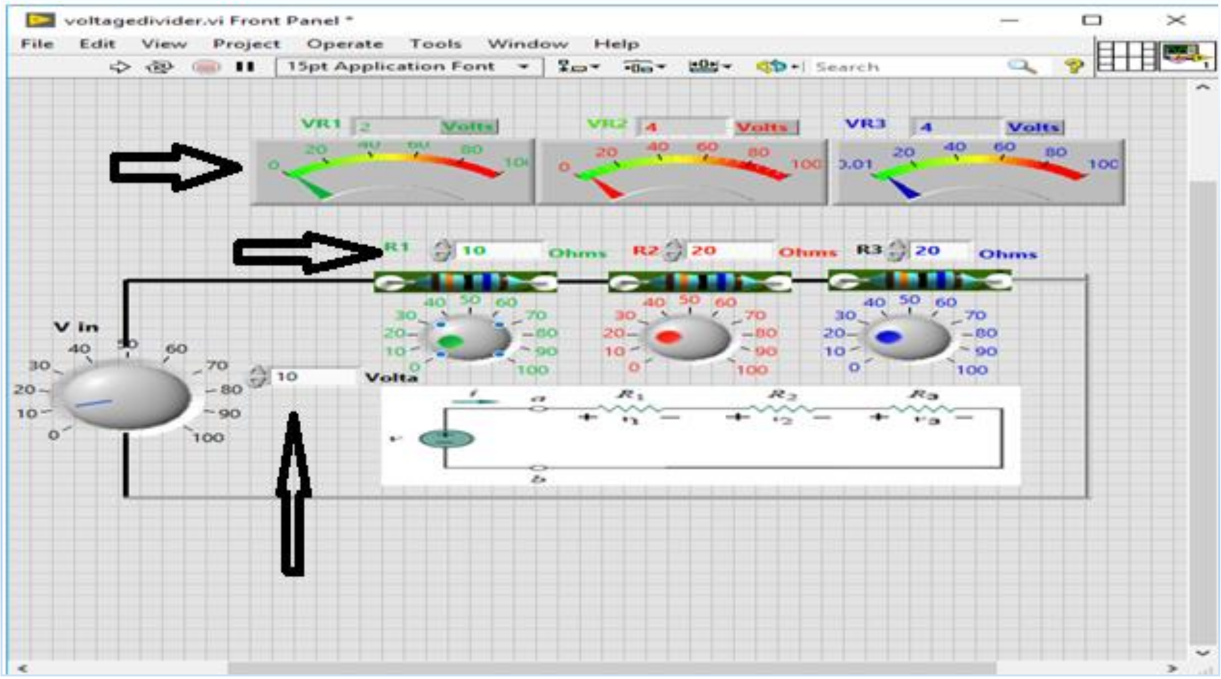


Figure 3.22: Online interfaces (experimental results)

As can be seen in Figure 3.22 when *R2* and *R3* twice *R1*

Based on the calculation:

The voltage across *R1*, ($\boldsymbol{V_{out} = V_{R1} = \frac{V_{in}R1}{R1+R2+R3}}$)

VR1= (10#100)/ (10+20+20)

VR1=100/50

VR1= 2 Volts

And *VR2*, *VR3* twice *VR1*

Because *R2*, *R3* the same value that meant the same cross voltage

The voltage across *R2, 3*, ($\boldsymbol{V_{out} = V_{R2,3} = \frac{V_{in}R2,3}{R1+R2+R3}}$)

VR2, VR3= (10#20)/ (10 +20+20)

VR2, *VR3*=200/50

VR2 =*VR3*= 4 volts

This means that *R1* is half *R2* and *R3*

$VR1$= 2 volts equally half of $VR2$ and $VR3$=4 volts

Vin =total voltage across all the resistors

Vin =10 Volts

$Vin = VR1+VR2+VR3$

Vin =2+4+4

Vin =10 volts

3.4 Summary

This chapter represents the described design procedure used to set up the RAL. It provides a description of and explains an overview of the RAL task activity design, followed by illustrations of the Voltage Divider software and experiment. Also, it explained the task activity requirements, the learning objectives, and how they were achieved in the application of the activity in the experiment and the challenges involved (Owings, 2014). Details were also presented on the last part of the procedures regarding participants' roles and responsibilities in their collaboration and how to publish the Voltage divider on LabVIEW into internet pages as an online activity. The next chapter, Chapter 4, describes the methodology for this research, including the data collection instruments and how the data aligns to the research questions, the approach to the data analyses and, finally, considers issues of data trustworthiness in terms of triangulation, ethical considerations and limitations.

Chapter 4 RESEARCH METHODOLGY

Research Methodology

The previous chapter explained how the research RALs activity was designed using the LabVIEW software and provided the instructional procedure to be applied in the collaborative learning situation. The application of LabVIEW in terms of participants' learning and involvement in the Voltage Divider Experiment was also explained in detail from the stage of launching the instrumentation and the application of various formulae and calculations, through to publishing on the website. Chapter 4 provides an overview of the research design and method that focused on qualitative data collection and analysis using a case study approach. It is divided into eight sections, as shown in Figure 4.1. The chapter justifies the research case study approach, presenting the conceptual research framework, an explanation of the sampling of participants, details of the quality of the research in terms of the trustworthiness of the data and the ethical considerations. It also outlines how the data collection aligns to the research questions.

Central to the case study was the research task activity that was designed to foster participants' face-to-face collaborative learning in the RALs environment. It is reiterated that this was achieved by applying the social constructivist Doolittle eleven principles of learning experience design. This allowed the researcher to add online collaboration to the advanced activity task and then adopt an educational framework for the specific purpose of following the students' learning activities by examining their collaboration through the case study.

4.1 The Research Approach

The most appropriate methodology for this investigation was a case study. Case studies are considered the most suitable method to conduct exploratory research and when the research is aiming to develop or construct new knowledge or theory (Cohen, Manion, & Morrison, 2018). Given the focus of this study on creating a collaborative learning environment informed by the Doolittle (1995) eleven principles of learning experience design, Kagan's PIES four outcomes of collaborative learning, Dillenbourg's elements of collaborative learning and social constructivism, the researcher takes an interpretivist world view. The in-depth focus on the RALs' collaborative learning phenomena provided through case study is seen as the best way of revealing the details of the students' experience, their potential collaborative learning dialogue and their knowledge and skills generation (Scager et al., 2016). Moreover, quantitative data collection through, for instance, a survey would not be appropriate because it was necessary to have students experience the reality of the RALs learning environment since that was central to the research. In addition, the critical focus of using the LabVIEW software was both authentic in approach and less costly and time-consuming, which are important aspects of the research. The RALs is also a contemporary alternative to hands-on traditional Lab work, which can be logistically challenging and expensive in higher education.

Thus, the case study method was chosen in order to test the theoretical underpinnings of the online collaboration generated by the Voltage Divider Experiment in RALs and the specific related learning activities. This enabled the researcher to gain a deeper understanding of the complexity of collaborative learning activities via the use of multiple sources of evidence. The use of case studies to investigate collaboration in remote access laboratories in-depth was particularly appropriate, as also advocated by Cohen (2017). Through the use of multiple data sources, the data reliability can be enhanced for data triangulation. Specifically, this case study research method was guided by Yin (2011). The design and data collection also took into account Dillenbourg's (1999) elements of collaboration.

4.2 Research Questions

This research sought to investigate the current theory and practise with regards to the potential of pedagogical change in engineering education through the use of RALs, where social constructivist practices were applied to higher education students in fostering collaborative learning in Lab work, as opposed to traditional hands-on mode. Thus, as outlined in Chapter 1, Section 1.4, the following research questions guided the study:

RQ 1: To what extent is collaborative learning in remote access laboratories accepted by engineering students as a workable alternative to traditional LAB work?

RQ2: What are the actual factors that need to be considered when adopting a collaborative approach to learning in RALs?

Sub-RQ 2.1: What does a shift to a collaborative learning approach in RALs require in practice?

RQ3: What are the actual significant benefits of adopting a collaborative approach to the RALs?

In its investigation of how to support student collaboration in RALs the research drew upon the Doolittle (1995) principles of learning experience design (see Chapter 2, Section 2.5), and Kagan’s (1992) four essential outcomes of collaborative learning (PIES) (see Chapter 2, Section 2.8. Additionally, Dillenbourg’s (1999) theoretical elements of collaboration learning (the situation, interactions, learning process and effects) were employed to determine the occurrence of collaboration in the online context.

From the literature, it was hypothesized that collaboration in a face-to-face mode, as espoused by Doolittle’s (1995) principles of learning experience design, was useful in gaining an enhanced understanding of this process, based on social constructivism theory. The research also aimed to develop and document a proposed framework to guide collaborative learning for the specific RALs environment.

4.3 Case Study

Research utilising case study has grown in reputation as a practical methodology for investigating and understanding complex issues in real-world environments. Case study designs have been used in several disciplines, especially social sciences, education, business, law and health, to address a wide range of research questions (Harrison, Birks, Franklin, & Mills, 2017). The continued use of the case study to understand the complexities of institutions and their practices and processes, including pedagogy and learning in higher education, has demonstrated its usefulness for researching learning contexts such as the practice of learning in RALs, as in the present research (Harrison et al., 2017). This is also reinforced as an appropriate research design to conduct the present investigation by the work of Anthony and Jack (2009), Brown (2008), Creswell and Creswell (2017) and Merriam and Tisdell (2015). Thus, the case study methodology was chosen in order to better understand the processes of learning in RALs and framing activities and tasks that facilitate collaborative learning. The approach can be used to gain a broader perspective and enable the researcher to understand the complexity of collaborative activities in which multiple sources of evidence are collected for analysis. The main objective of case study research, therefore, is to conduct an in-depth analysis of the target phenomenon, within its context, and understand this situation from the viewpoint of the participants (Merriam & Tisdell, 2015; Stake, 2006; Yin, 2017).

Furthermore, case studies are appropriate when the purpose of the study is mainly to explore how things are becoming what they are (Merriam, 1998). Given that the purpose of the current research is to study the effectiveness of online collaboration in RALs, a qualitative case study is considered a best-fit design. Because the phenomenon and the context are not always distinct from the reality of life in a case study, other technical characteristics, including data collection and data analysis strategies, become an important second part of the technical definition according to Yin (2017). He notes that: “there are three types of case studies: exploratory, descriptive, and explanatory” (p. 18). In this study, an exploratory case study was selected as the most appropriate. This exploratory case study ensures the ability to provide a complete picture of collaborative learning in RALs within context, as well as an explanation of the intervention and the real-life context in which collaboration occurs.

A case study approach using qualitative data collection methods was adopted to explore the phenomenon and identify factors that facilitate and/or inhibit students' collaboration in RALs. As a result, the case study allowed the researcher to study collaborative learning in RALs to achieve the most comprehensive answers to the research questions.

The case study approach is also appropriate for research that aims to generate new insights into a phenomenon where other methods would be unable to do so (Runeson & Höst, 2009). Unlike experimental designs in the category of positivism, in case studies the researcher has some flexibility to study sudden or dramatic phenomena of interest that emerge throughout the research process (Eisenhardt & Graebner, 2007). In experimental designs, data collection is tightly defined or filtered according to survey questions or item design in advance. Thus, the case study can allow the researcher to develop new theory and understanding and, in this case, deeper insights into contemporary practices in Lab pedagogy and particularly the relevance of pedagogical change to collaborative learning in the context of RALs.

4.4 Researcher roles

4.4.1 Overview of the researcher's practical research activities

The researcher's role in the research varied in intensiveness and extensiveness (Jarvie, 1986; Marshall & Rossman, 2006), including participant observer. As Jarvie (1986, p. 152) notes: "the success of the method . . . derives from exploiting the situation created by the role clashes insider/outsider, stranger/friend . . . more engaged with participants than in the passive role". In this regard the researcher carefully prepared the materials to support the simulated online Lab experience and monitored the sessions. In addition, he ensured the participants were fully informed about the research purpose and process (and in keeping with research ethics approval). The research materials also supported the participants' roles e.g. leader guide and sequential tasks to be conducted with the Voltmeter Divider, and ensured they knew how to use the equipment. This helped build a sense of trust and reciprocity and helped facilitate an authentic collaborative learning focus and subsequently the individual interviews to create a frank and open discussion. Thus, the researcher had a dual role as researcher and instructor, where he:

- designed the tasks by using LabVIEW software and used them as a basis for developing Doolittle principles specific to RAL collaboration,
- developed recommendations to facilitate online collaboration and then an instructional framework for the learning activity to be tested in the case study,
- developed and documented a framework to guide collaborative learning in an online environment for the specific online learning activity (the Voltage Divider Experiment),
- modified the guidelines which contributed to the preparation of the present research and the processes,
- refined the research outcomes in relation to the students' understanding of learning through collaboration in RALs,
- helped participants to used video conferencing tools (collaboration tools) to support the collaborative learning experiences,
- invited the participants through the course examiner (lecturer in USQ who was responsible for teaching and examining the course) approval via a post on the study desk,
- observed the process of the collaborative activities in each group by recording the whole activity by the conference tool; and, as a result of interviewing and observation, individual file records were made available for this research,
- observed online collaboration in the remote laboratory to draw information not obtainable via other methods, and
- recorded interviews and then transcribed to gain greater insights and precise data for phase analysis to achieve a transparent coding process.

4.5 Research Conceptual Framework

The overall research conceptual framework is shown in Figure 4.1. The three main contributing components are (1) literature review; (2) hypothesis; and (3) case study. The literature review provides the foundation/theoretical basis for this research and covers both collaborative learning and remote access laboratories in identifying the existing status of knowledge in the field to provide a justification for the research problem and the need for the present research. The second component of the framework is the hypothesis theory that refers to the role of the Doolittle (1995) eleven principles of learning experience design that the research draws upon to underpin and validate the design of the RALs learning activities/task. This contributed to the ability to create a collaborative learning space equivalent to face-to-face environments in the context of remote laboratories. This was seen as a strategy to enable the researcher to subsequently develop recommendations to facilitate online collaboration and design an instructional framework for the specific learning activity. Case study research gives an understanding of the processes of online collaboration in those online courses and can be used to gain a broader perspective and to understand the complexity of collaboration activities in the context of remote laboratories in which multiple sources of evidence were used.

As shown in Figure 4.1, adopting constructivist eleven principles of learning experience design (Doolittle 1995) guided data collection from students via interviews, observations and student task reports and guided the learning activity. From an individual activity, this project looked at an activity to be performed via a collaborative approach, as shown in Steps 3 and 4, in online course design. Moreover, it focused on how to modify it—as shown in Step 5. In the redevelopment stage, the researcher worked with the activity instructions to progress to a new context, Steps 3 and 4. The researcher developed and documented a framework to guide collaborative learning in an online environment for the specific online learning activity (the Voltage Divider Experiment). The selection of this learning activity was from the electronic course for implementation. The learning activity was analysed and evaluated in keeping with the principles. Based on this analysis (4) of the activity, changes were made to redevelop (5) and then trial the method with students by collecting data (see Step 6) about the learning activity implementation. After the student trial, the data were collected from students via interviews, observations and student task reports (Step 7). The PIES four outcomes of collaborative learning (Kagan, 1992) and Dillenbourg’s (1999) theoretical elements of collaboration are also shown in Figure 4.1 to illustrate their use in the analyses that contribute to answering the research questions (8). They also contribute to ascertaining whether the RALs activity is ultimately successful or not, including whether collaboration occurred. With the same data, further analyses are shown to be conducted in order to examine the relevance of the Doolittle eleven principles of learning experience design and how adequate they proved to be for current learning in RALs and the need for collaboration. Furthermore, instructional guidelines were developed for the learning activity and were implemented during the delivery of the RAL course prior to the research. This was established by using thee four outcomes of collaborative learning (PIES) (Kagan, 1992) and Dillenbourg's (1999) theoretical elements of collaboration to determine the existence or otherwise of these elements. In the absence of such collaboration, the researcher planned to investigate the cause as to why the collaboration was not occurring or accruing (Step 8). Based on those findings, the researcher modified the guidelines which contributed to the preparation of the present research and the processes. After that evaluation using these data, the instructions were improved accordingly (9, 10). The revision and analysis of the guidelines took into account the research questions. In the end, the study progressed to reviewing their effectiveness and their implementation and ascertaining the extent of collaboration and, subsequently, the refinement of the facilitation of this framework.

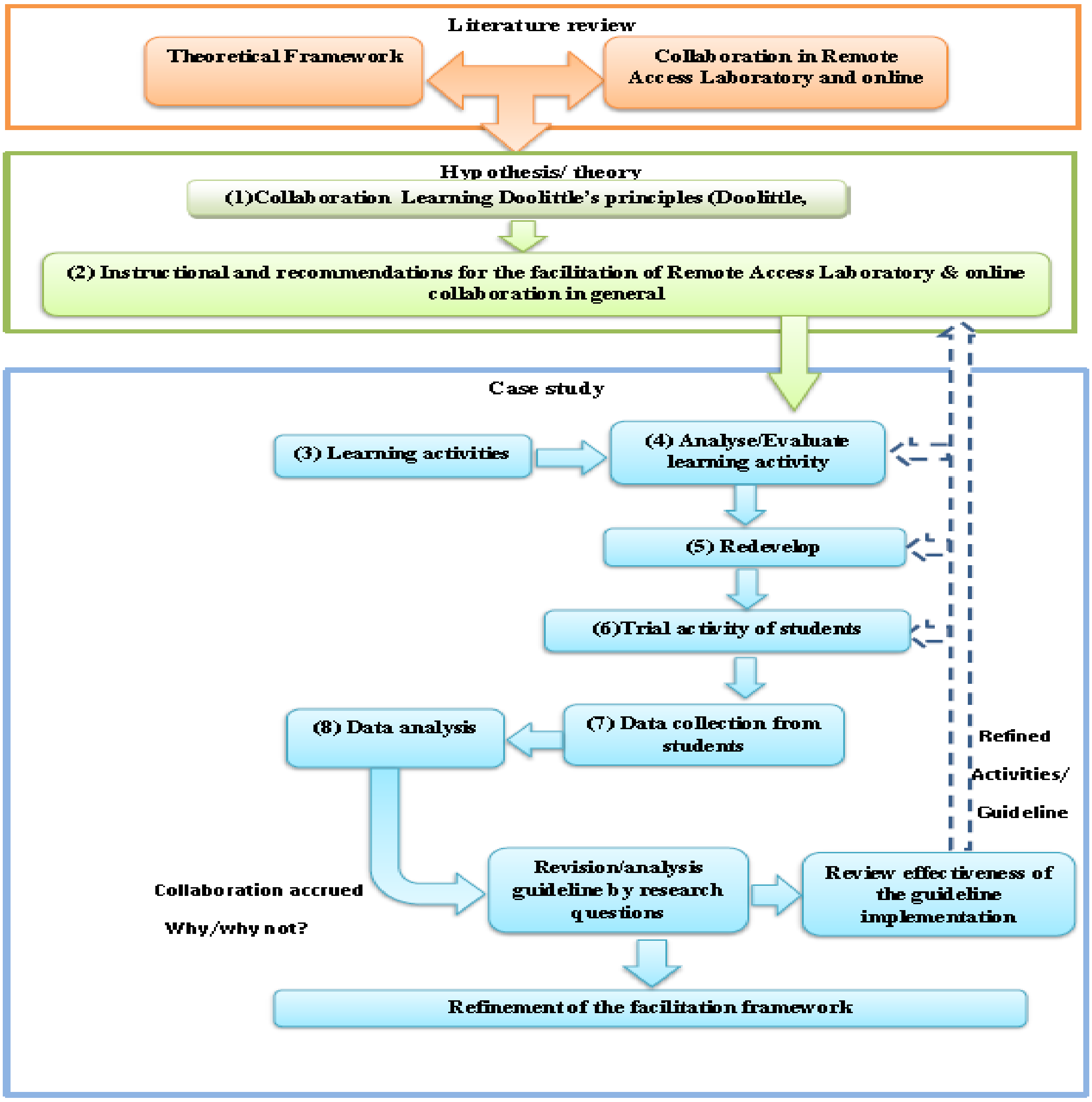


Figure 4.1: Research conceptual framework

4.6 The Research Process

Table 4.1 provides an overview of the stages of data collection and the way these data align to answering the research questions. In Stage One the researcher focused on the design of the RALs collaborative learning activity and how it should be created to foster a collaborative approach to learning. It focused on drawing upon the review of the literature in relation to the underpinning theory, namely, Doolittle's eleven principles of learning experience design, Kagan's (1992) PIES - four outcomes of collaborative learning, and Dillenbourg's (1999) theoretical elements of collaboration (situation, interactions, learning process and effects). Stage Two involved the selection of participants in the study's trial of engineering LAB work in a RALs context. Data collection occurred through a video recording of the students' collaborative learning sessions (2). Each was of approximately 120 minutes duration. Subsequently, the results of the students' completion of the RALs learning activity task sheet formed part of the analysis to investigate the learning. Following this, in Stage Three, qualitative data were collected through semi-structured interviews with a sub-sample of those students who had participated in the RALs learning experience. Each of these interviews was of 60 minutes duration. This final stage also involved the use of mind mapping as a strategy to explore the findings and determine knowledge development.

Table 4.1.

An Overview of the Stages of Data Collection and Alignment of Data to Answering the Research Questions

Stages	Stage 1	Stage 2	Stage 3
RQ1	To what extent is collaborative learning in remote access laboratories accepted by engineering students as a workable alternative to the traditional LAB work?		
	X	X	X
RQ 2	What are the actual factors that need to be considered when adopting a collaborative approach to learning in RALs?		
		X	X
RQ 2.1	What does a shift to a collaborative learning approach in RALs require in practice?		
	X	X	X
RQ 3	What are the actual significant benefits of adopting a collaborative approach to the RALs?		
		X	X

(X notes the relevance of the data to answering each research question and accrual across stages)

The case study design, therefore, involved two groups selected students from the University of Southern Queensland (USQ) who were enrolled in practical engineering courses. The purpose of conducting a pilot study was to examine the feasibility of an approach used in a study. It also helps guide the interview process and questions and improve the activity itself and the results can impact on feasibility and identify modifications required in the design of the activity. The pilot study is instructive in that it points to modifications needed in the planning and design of the actual study efficacy trial to ensure the Voltage Divider Experiment was operating appropriately in the RALs context. Participation in this study was voluntary. The sampling strategy was purposive, also known as judgmental, selective or subjective sampling, which considers the judgement of the researcher; and this is the type of purposive sampling technique that is used in this research to glean knowledge from individuals that have expertise in engineering. Multiple sources of triangulation evidence were used to enhance study accuracy (observation, semi-structured interviews, and student task report). The invitation to recruit students was initially presented on a relevant course study desk (Appendix C). The course study desk is the USQ Learning Management System. It allows students to access all course content (educational materials) online. Also, they can access it on multiple devices which allow them to be flexible with their time and to study on the go. However, the researcher also used the snowball technique because the engagement of participants was initially low following an online blog to attract participants (see Appendix D). Snowball sampling is something as simple as passing on student information statement and advertisements. The method combined the chain referral sampling with a recruitment process based on a blog (Baltar & Brunet, 2012). Also, each respondent can act as a recruiter until the desired sample size is reached. The main advantage is the recruitment bias can be controlled in terms of the oversampling of respondents (Baltar & Brunet, 2012).

To establish the quality of the research design, four tests related to social research (construct validity, internal validity, external validity and reliability) were considered regarding the study. Following the selection of the case study research approach, the data analysis methods were discussed in terms of qualitative content analysis; and NVivo software Computer-assisted Qualitative Data Analysis (CAQDAS) was used to fulfil these requirements.

4.7 Selection of Participants and Groups

The participants for the research were USQ students enrolled in practical engineering courses, or who were engaged in practice activities in the Faculty of Health, Engineering, and Sciences. Such students may be from different linguistic and cultural backgrounds and have English as a second language. As a purposively selected small sample of participants, the students were randomly divided into two groups of five. A total of ten participated in the follow-up semi-structured interviews. The ideal group size for the RALs activity was considered 3 to 5 to ensure the opportunity to maximise collaboration. Thus, the participants were required to work as groups where their way of working was structured through the use of a team leader, written instructions on the process, and tasks for both the leader and team members. This included the need for participants to conduct the Voltage Divider Experiment to eventually achieve consensus on the answers to the calculations involved.

From the research ethics perspective, any imposition on students was considered minimal because students' participation was voluntary. In addition, the research activity provided the students with an additional relevant learning opportunity from which they could benefit in co-constructing new knowledge through the collaborative approach. The research was not related to the students' course assessment; therefore, it did not present issues in this regard. Neither was the researcher connected in any way to the students' course assessment. Besides the sampling approach being described as purposive, it also involved an element of convenience sampling because students typically attend on campus for LAB work, so for this research purpose they participated at a distance through RALs. Their maximum time commitment for the research was three hours, being two for the RALs activity and one hour if participating in the interviews—plus some time for becoming familiar about the aims of the research and its requirements.

Thus, the students were placed under the same conditions, but in different remote locations. Manual instructions were prepared and trialled to support the conduct of the LAB work and the role of the team leader, including a guide to help the collaborative approach in the online environment. Eleven participants were accepted to participate in the interviews; however, one withdrew. The activity represented a standard practice activity, and participants needed to have at least sound communication and computer skills.

Purposive sampling was used in this research as the primary sampling strategy (Noor, 2008). Creswell (2018) recommends it as a form of variation sampling. In this type of sampling, the researcher identifies participants to reflect the strengths and weaknesses of observed phenomena. Considering the criteria, students were selected because they could provide the necessary information needed for participation in the research. Approval to approach the university's students was also obtained from the Associate Dean (Students) (see Appendix E and Appendix K) as part of the ethical requirements.

Three basic methods can be utilized to carry out group selection—self-selection, random assignment, and selection based on a standard (Gunderson & Moore, 2008). In this study, the group was self-selective as they needed to take into account the times that they were available to participate. Finegold and Cooke (2006) and; Gould (2012) advise that small groups are considered as more suitable for group discussions and encouraging the equal contribution of group members. Also, Springer, Stanne, and Donovan (1999) and Pai, Sears, and Maeda (2015) found that small groups provide students with a better learning experience and, ultimately, more significant academic achievement. As well, Brindley, Blaschke, and Walti (2009) reported that students often prefer working in small teams over large study groups. Collaboration in a small group has been notably recognised as both advantageous and appreciated by students. The selection of small groups also helps and enables students to identify with each other and correct misconception more easily and quickly, as well as improve understanding of the topics being learned.

At the beginning of the process of in-depth interviews, the sample for this exploratory research has been deliberately, rather than randomly, selected. Participants were invited by the researcher following course examiner (lecturer in USQ who is responsible for teaching and examining the course) approval via a post on the study desk (Appendix F). Thus, the opportunity to volunteer to participate was advertised on the course study desk. The researcher communicated with all the participants following their voluntary response to the invitation to the course study desk placed by the course examiner. Because there is not much data, the researcher did not use university equipment, in accordance with ethical guidelines: By utilising blogging and snowballing to recruit students, there was no requirement to use university equipment.

During the first contact with the course examiner, the researcher introduced himself and gave a brief description of the purpose of the research. The researcher received information about the students who he needed to be part of the activity. This information includes their names and their contact details such as 'phone numbers and email addresses. During the Voltage Divider Experiment, the researcher invited them to participate in in-depth interviews. After the activity, the researcher contacted students and requested them to participate in the research interviews. As a result, the researcher obtained their acceptance for the interviews from every segment and every size classification. The researcher then created a final list of all students who had agreed to participate in the study and interview process.

After students' completion and signing of the consent form (see Appendix L) the researcher moved towards initiating the research and collection of data from the participants. The participants had the option to agree or disagree to participate in the research and were advised they were free to withdraw at any time.

4.7.1 Ethical considerations

Ethical clearance was obtained through the USQ (Approval No. H14REA079) refer Appendix I, and signature approval was received from students to participate in the research activity, including interviews and acceptance of being audio/video recorded in the RALs. There are ethics and standards relating to all fields of research that each researcher must follow. Studies such as the current study can only be acceptable in such circumstances if all ethical standards are met through research or study of the results of the research. For example, the researcher must preserve the privacy and confidentiality of participants; and a researcher cannot reveal the identity of each participant. In this regard, privacy and participant information was kept on security and labelled accordingly for each participant such as (Y01, R02, O03, R04, R05, N06, M07, Y08, S09 and O010) to meet the national ethical standards required by the university in relation to the ethical conduct of human research and they provided detailed guidelines for this research to ensure that all potential ethical issues were dealt with. The rules of ethics applied to all ethics-related documents, including the participant consent form; participant information sheet; and consent form for observation (see Appendix L) and recording activity (see Appendix M). Some comments arose about how sound recordings were to form part of the research methodology and other feedback regarding the pilot study data and storage location. The researcher made the necessary adjustments in relation to each comment emerging in the ethics process and gave details to provide clarifications.

Qualitative methods were used to collect and analyse data. Observation, interviews, collaborative activity, and audio-video recordings were the basis for collecting information considered necessary for this study. Data collection occurred in the first and second semesters of 2018. The case study method involving collaborative learning also supported the creation of meaning because students were able to share their ideas that they may not have thought of independently (Babbie, 2004). Semi-structured rather than structured interviews were employed because they offer sufficient flexibility to approach respondents differently, while still covering the same areas of data collection (Noor, 2008). The interviews were video, and audio recorded to secure an accurate account of the conversations and avoid losing data since not everything can be documented by hand during an interview. Finally, every recorded interview was numbered and labelled with the code of the interviewee in order to avoid any duplication. The researcher used Kagan’s (1992) and Dillenbourg's (1999) theoretical elements of collaboration to assist in formulating the interview questions, given their relevance to the theoretical underpinnings of the collaborative learning practice and anticipated outcomes.

Besides in-depth interviewing, the researcher observed the process of the collaborative activities in each group by recoding whole activity by conference tool; and, as a result of interviewing and observation, individual file records were made available for this research. This was where the researcher observed online collaboration in the remote laboratory to draw information not obtainable via other methods. What was observed by the researcher related to the physical setting and environment within which the collaboration occurred. Observation and analysis of the collaborative dialogue were able to generate deeper insights and a better understanding of the RALs potential collaborative activity and task under study.

4.7.2 Implementation of the Case Study

It was proposed that subject to ethics approval; the case was used to investigate the effectiveness of the online collaboration framework learning activity in the Voltage Divider Experiment. At the start of the case study procedure, the students took part in a learning activity where they learned about the collaboration tool to be used (video conferencing using ZOOM). The students were placed into small groups but attending from their various remote locations and the interaction via zoom was synchronous. They also participated asynchronously, that is, from different locations via the Internet and communicating with the researcher aside from the RALs learning activity. Each student was provided with the instructional activity guide, which was designed to direct them in the collaborative problem-solving required in the Voltage Divider antivirals session. The pilot study was conducted first, which comprised a smaller pilot version of the qualitative data collection process for the study. This ensured that students were familiar with the video conferencing tool and setup of the Voltage Divider Experiment and their team peers. As noted by Cohen (2017), a pilot investigation is usually a small-scale pilot conducted before the main investigation that is intended to assess the adequacy of the research design and the instruments to be used for data collection. The researcher agreed with their view that the data collection instruments need to be piloted as an essential part of the research design. For this reason, in this study, the researcher also constructed a feedback form for the pilot as recommended to help evaluate the activity task and interview questions. This also contributed to increasing the reliability and trustworthiness of the data. The pilot was conducted with a group of colleagues as volunteers, who were considered to have expertise in the field. The pilot ensured the activity worked well, and the conference tool worked to synchronize the activity task for the leader of each group to enable them to prepare them and identify any technical issues prior to the actual data collection.

The pilot activity was administered in March 2018, and the interviews were conducted after the activity completion to revise the interview questions for the main study. The results of the pilot helped the researcher to clarify and review the questions before administering these two activity sessions and the ten interviews in the actual research. When the researcher conducted the pilot study, the researcher asked the participants to enter the starting time and the end time on the student task sheet to help the researcher calculate the total time needed to complete the activity and approximate time for each interview. In addition to piloting the activity and interviews, the researcher fine-tuned the pilot feedback questions to make them easier to understand, and identified which questions needed clarification and also to determine the time suitability. Another reason for conducting a pilot study was to gain real-world practical experience in administering the activity and interview and as preparation for the researcher to be adequately equipped before gathering data for the main study. Ultimately, the researcher had to revise the activity task and interview questions based on small technical problems.

Therefore, this study also examined the activity and how collaboration ensues and, thus, assisted the researcher in solving any issues before the start of the real project. The timeframe encompasses two parts: the first iteration of the cycle pilot study; and the second iteration was implemented through the actual research project. The timeframes, therefore, encompass two parts: the first iteration of the cycle pilot study; and the second iteration was implemented through the larger actual research project and experienced a more extended period of time.

In the Voltage Divider Experiment, the students learnt about the voltage divider and series resistance in circuits, which works by splitting the input voltage amongst its resistors. All this was achieved in the RALs. This is traditionally an individual task but can be shared collaboratively in the context of this research. This was because the activity was structured for students to share their predicted outcomes and, if there was uncertainty, discuss any differences in results; the collaboration accrued dialogue/critical discussion between students and the team leader to arrive at the desired solution. The activity time commitment was 1-2 hours—to allow the development of recommendations for a specific learning activity for online collaboration to occur. The researcher developed recommendations to facilitate online collaboration and then an instructional framework for the learning activity to be tested in the case study.

The main limitation of the study was the fact that it is a single case study of students involved in a specific LAB task in electrical engineering, where a collaborative learning framework was implemented, and the research was exploratory. However, the research design involved the triangulation of data to investigate the impact of the learning experience both from the perspective of the students themselves and from the evidence of recordings of the collaborative interactions. The analyses of students' dialogue stemming from their collaboration in the RALs' virtual learning experiences and interview data regarding their perceptions of their learning experience were also examined in relation to the underpinning theoretical principles—which added greater depth to the analysis and synthesis. While it may also be argued that the findings would be relevant to the use of similar structured virtual learning experiences, it is recommended that the research might be replicated and investigated across a variety of tasks as multiple cases. This would strengthen the pedagogical aspects of the research and the suitability of the learning framework across disciplines.

4.7.3 Data collection

Interviews and observation were used as the basis of collecting data for this study. The data collection and analysis phase were guided by Kagan's (1992) and Dillenbourg's (1999) theoretical elements of collaboration, which are grounded in social constructivist theory. The case study benefited from the prior development of theoretical propositions to guide data collection and analysis. As noted earlier, NVivo software was applied to the data analyses in the search for themes related to the latter theorists.

4.7.3.1 Participant observation

Besides in-depth interviewing, the researcher observed the process of collaboration activities in each group (see Stage 2 as shown in Table 4.1) and, as a result of interviewing and observation, individual file records were compiled. The researcher's observations provide ways to examine and direct the non-verbal expression of emotions, determine the interaction between team members and how to interact with them, as well as understand how participants communicate with each other. This approach can assist in verifying how much time is spent on different activities, and the activity can also be recorded and observed to help in triangulating the interview and reporting data (Schmuck, 1997).

A study by Kawulich (2005) indicated that participatory observation includes the researcher's participation in activities over the whole activity time. This enables the researcher to monitor members at their activity and gain a better understanding of behaviours and interactions. Also, the process of conducting observation is seen as including participation in groups and other informants, as permitted by group members. This helps the researcher clarify the findings along with the data analyses to help develop a narrative that helps explain the findings.

Participant observation has been used in a variety of disciplines by collecting data about people, processes, and cultures in qualitative research (Kawulich, 2005). The entire activity conversation was recorded via video and audio, as well as note-taking being employed. As a direct observer (e.g., of human actions or a physical environment) the researcher was involved in observing the collaboration in the RALs where information not obtainable via other methods was drawn. What was observed by the researcher related to the physical setting and environment within which the collaboration took place. Observation generated insights into the pedagogy and collaborative activity and helped gain a deeper understanding of the collaboration activity under study.

Observation provided the researcher with the means to check the non-verbal expression of feelings and identify those who interacted with them, besides understanding how participants communicated with each other. Kawulich (2005, p. 2) defined "participant observation as the process enabling researchers to learn about the activities of the people under study in the natural setting through observing and participating in those activities". The participant observation provides the context for the development of sampling guidelines and interview guidelines.

4.7.3.2 Semi-structured interviews

Stage 3 of the research, as shown in Table 4.1, involved the data collected as evidenced in Kagan's four elements to help determine the level of collaboration and as outcomes of collaborative learning: (1) Positive interdependence; (2) Individual accountability;

(3) Equal participation; and (4) Simultaneous interaction (PIES). The instruments used for data collection were audio/video recording observations, interviews, and reporting on task. The data were collected to ensure that the collaboration occurred between the participants and that the principles of face-to-face activities operate in the online and RAL environment.

The interviews were audio-recorded to secure an accurate account of the conversations and avoid losing data, since not everything can be documented during an interview. Every element of the interview was recorded (that is, open-ended discussions with crucial participants) with the interview time commitment being between 30 minutes to 1 hour and with the investigator undertaking transcription. The choice of semi-structured rather than a structured interview was employed because it offers enough flexibility to approach respondents differently, while still covering the same areas of data collection.

The interview was recorded and labelled with the code of the interviewee in order to avoid any duplication of information and also considering the ethical issues of privacy and secure information. The interviews served as a data-gathering instrument for the research. The researcher used Kagan’s (1990) and Dillenbourg's (1999) theoretical elements of collaboration to determine the level of collaboration in the given context to formulate the interview questions for these perspectives. Most of the laboratory sessions involved interviews using semi-structured questions to elicit responses from the various categories of student respondents.

DiCicco Bloom and Crabtree (2006, p. 315) defined semi-structured interviews as being “organised around a set of predetermined open-ended questions, with other questions emerging from the dialogue between interviewer and interviewee/s”. Semi-structured interviews are useful for gaining detailed information about people, ideas, opinions, ideas and behaviours or to explore new issues in-depth. It is often used to provide the right environment for other data, offering more understanding of the full picture of what happened in the study and why (Boyce & Neale, 2006). The final step of data collection was an interview. Randomized selections of 11 participants from the two groups were identified for interviews by the researcher. Participants were interviewed online and face-to-face (the interview time taking between 30 to 70 minutes), and all interviews were recorded.

In these interviews, the researcher explained the purpose of the interview to receive more in-depth information about their experience in the collaborative activity and asked all participants to sign an interview consent form after completing his or her participation on collaboration in the laboratory. A recorded interview was then transcribed by the researcher to gain greater insights and precise data for phase analysis. The focus of interviews is to provide participants with the opportunity to reflect on their collaboration in a remote access laboratory.

An interview protocol was carefully organised to help the interviewees describe their experiences with as much detail as possible. The protocol for the interview involved planning and introduction, followed by establishing rapport and neutrality (Gaskell, 2000; Kvale, 1983). Preparation for the interview protocol consisted of defining the required information regarding the research problem (Dick, 1998). The introduction was developed to inform the selected respondents about the interview. The selected respondents were approached by telephone and email. During the phone and online interview, the interviewer introduced himself and provided a brief description and primary purpose of the research topic.

Further information included the reason they were selected as participants, the type of information that was required, and what would be expected from their participation (Carson, Gilmore, Perry, & Gronhaug, 2001). The research followed ethical codes of conduct in qualitative interviewing (Carson et al., 2001). Ethical clearance was obtained through the USQ (Approval No. H14REA079). After initial introductions, the researcher ensured that the interviewee went through the participant information sheet (see Appendix G) and signed the consent form (refer to Appendix J).

The participant information sheet and the consent form provided information about the research topic, the contact details of the researcher, the rights of the interviewee, and the purpose of audio and video recording of the interviews (refer to Appendices A3-5.) Confidentiality of interviews is emphasised by Rao and Perry (2003). The selected respondents were informed that they were free to withdraw their consent to interview at any point of time during the process (Johnson, Dunlap, & Benoit, 2010). The decision whether to take part or not or to take part and then withdraw, will not affect the participant treatment and relationship with the USQ or where the participant is employed.

The goal of the interviews was to explore the challenges and constraints, the advantages and disadvantages and make recommendations for the use of collaboration in RAL online and help improve the effectiveness of online collaboration practices.

The question that constantly arises is how many interviews should be conducted in the data collection stages? After analysing the interview responses, it can be indicated that the *saturation* in the interview responses occurs until no further revisions were deemed needed. In other words, if there is no new knowledge acquired or the information becomes repetitive, then the interviews should be halted (Guest, Bunce, & Johnson, 2006). Saturation is based on some aspects such as the research questions, research problems, the skills of the interviewer and data analysis methods. Sensing (2011) pointed out the difficulty of reaching saturation levels in the conduct of interviews. A total of 11 interviews were carried out with students at the University of Southern Queensland. The data reached saturation level within the 9 interviews due to the information becoming repetitive, and when the researcher noticed that there was no more new information emanating from the interviews. More information about the interviewees is shown in Table 4.2. The interview participants used in this research numbered 11 interviewees. One interviewee was excluded from the analysis because the participant withdrew at the beginning of the interview.

Table 4.2

Participation Information

No	Interview code	Major	Date of interview	Type of interview	Period of interview
1	Y01	Mechatronic Engineering	15 May 2018	online	42 min
2	R02	Civil Engineering	25 May 2018	online	38 min
3	O03	Construction Engineering	26 May 2018	online	31 min
4	R04	Mechanical Engineering	26 May 2018	online	34 min
5	R05	Mechanical Engineering	26 May 2018	Face to face	48 min
6	N06	Electronic Engineering	30 May 2018	Face to face	46 min
7	M07	Electrical Engineering	07 June 2018	Face to face	52 min
8	Y08	Electronic Engineering	09 June 2018	Face to face	50min
9	S09	Electrical Engineering	12 June 2018	Face to face	58min
10	O010	Electrical Engineering	13 June 2018	Face to face	68min
11	K11	Construction Engineering	withdrew	##	##

4.7.3.3 Reporting student task

One of the critical data collection tools was providing the student with instructions on how to follow the activity and included questions about the activity itself. Student task overview of the task paper guides participants to the activity and provides links to a web site that can provide access to the activity and programs, and are directed to follow the initial instructions to make sure the voltage divider works by following instructions (see Appendix A and Appendix B). All participants were required to fill out this report (measurements), and results were compared with calculation from other results from a colleague regarding a question on collaboration. The data helps the researcher to make the decision on students' proficiency or if they experienced difficulty or ease of activity, and whether they engaged in effective collaboration in RALs.

4.7.4 Data analysis

Data analysis commenced at the beginning of the multi-activity as the researcher had access to several academic and practical courses in various semesters. For example, learning activity in electronic engineering, with refinements, to collect data based on the previous collection stage, rather than collect data first and then turn to data analysis. The transcripts were analysed inductively to determine themes that emerged from student responses (Zhang & Wildemuth, 2009). An inductive analysis was chosen as there is no evidence of any previous studies that evaluated the use of a remote laboratory to work collaboratively with the aim of developing critical thinking in any domain of education. Words and phrases with similar meanings were identified, coded and then organised into categories that best represented the emergent themes. Coding of data means to transform data into a form understandable by computer software such as NVivo software, then the researcher used open coding: breaking down the data into themes, concepts, or master headings, and second-level categories, or subheadings. This information was then transferred into a brief outline, with concepts being main headings and categories being subheadings.

Axial coding occurred using the concepts and categories while re-reading the text. It was confirmed that the concepts and categories accurately represent interview responses, observations and video recordings. A table was then created to transfer the final concepts and categories into a data table. The themes were analysed and discussed by the author, and then independently reviewed by the supervision team in order to reduce the potential for bias (Pope, Ziebland, & Mays, 2000). The data collected from interviews and observation were then analysed. Activity which needs to take place from the start of data collection includes the researcher reviewing and selecting data that can answer the research question. The data is most pertinent to the study and always needs to be reviewed because the process is not straightforward and requires the judgment of the researcher. Also, clustered and categorised data (sorting the data into categories) can help save time and enable the researcher to go back to the data for further analysis. Thus, the data should be sorted on themes or categories, and the process includes managing the data; displaying the data; examining concepts and themes; synthesising the information and defining relationships between/among concepts and determining if the main elements of collaboration occur.

4.8 The Quality of the Case Study

Reliability and validity are traditionally associated with quantitative studies. They have also been applied to qualitative studies (Golafshani, 2003). Qualitative methods such as in-depth interviews should be evaluated for their dependability (reliability) and validity (Leung, 2015; Silverman, 2017). Reliability and validity are achieved by cross-checking with the interview transcripts to help improve reliability (Riege, 2003; Roberts, Priest, & Traynor, 2006). In this respect, Bernard (2017) and; Musante and DeWalt (2010) suggest that the use of this participatory observation increases the validity of the study, as the observations help the researcher to understand the context and phenomenon better; and add more power to the study while using additional strategies used with observation, such as interviewing, and document analysis. Yin (2011) declared that four tests might be considered relevant in judging the quality of research design: construct validity; external validity; reliability; and internal validity. In designing and undertaking case studies, various strategies are available to deal with these tests, though not all of these occur at the formal stage of designing a case study. Some of the strategies occur during the data collection, data analysis, or compositional phases of the research. The four tests of quality were addressed as follows:

4.8.1 Construct validity

Construct validity describes the course of operational measures appropriate to the concepts being examined in the validity of quantitative research and the extent of any measures of a measuring instrument that it aims to measure (Thatcher, 2010). There is a construct validity underneath in-depth interviews as the researcher constructs agreement regarding the meaning of constructing through carrying out several interviews, followed by interviewers discussing the purpose and interpretations of the data (Carson et al., 2001). In order to utilise the triangulation method, the data collection relied on multiple sources of evidence, namely interviews and observations, to converge information. Flexibility in the model allowed the researcher to re-evaluate and re-design both the content and process of the interview program, thus establishing content validity (Rao & Perry, 2003). Triangulation using interview questions was designed in this research for the critical constructs only to prevent iteration or non-concerned perception to the student (Carson et al., 2001; Rao & Perry, 2003). Each interview included paired wording of questions such that responses to the same issue were gained from a different perspective, such as: "*What did you think made such collaboration difficult? What was the big problem? (Explore: tasks, communication or process, leader, rewards for collaboration, technical skills, and work)".*

4.8.2 External validity

The research design used the theory of single-case studies. The research design benefitted from the use of social constructivism theory in a single case study. Theoretically, this study is based on several theoretical underpinnings, which provide the foundation for the study to construct collaboration in a RAL environment. For example, eleven principles of learning experience design considered by Doolittle are based on understanding collaborative learning through Vygotsky's Zone of Proximal Development theory. External validity often is of no importance for qualitative research, and an attempt to achieve this can seriously hamper overall strength. However, qualitative results are better generalizable in developing theories and not broader populations (Winter, 2000). Student selection for conducting in-depth interviews was based on the knowledge and experience of the researcher in this area of study, and because of the study being undertaken in a specialization of an industry that infects many people (Carson et al., 2001). For instance, all activity and interview participants were from a range of different engineering fields at university and a range of education levels, as well as from different backgrounds. Their choice was deliberately made to ensure that there is enough external validity present for exploratory purposes of in-depth interviews. Also, the qualitative findings of the current study have external validity; hence, the generalizable of these findings are applicable to other universities and could be adapted for other sectors outside higher education such as research centres and secondary schools. This approach assisted in ensuring the external validity of the study.

4.8.3 Reliability

Chatman (1992, p. 8) defined reliability of qualitative data collection and analysis as “the degree to which observations are recorded as consistent with some phenomenon during the lifespan of the inquiry”. It is measured by keeping records, transcripts and taking notes consistently, carefully selecting the participants and undertaking other relevant procedures for collecting qualitative data. While reliability measures should be designed to support accurate records of experiences and govern thoughtful exposure to a variety of observations and informants, validity measures should ensure that informants’ experiences are faithfully depicted in framing analysis and findings (Eschler, Taylor, & Palkar, 2015). Reliability is a measure used to ensure the consistency of the research procedures used to collect qualitative data (Wyse, Selwyn, Smith, & Suter, 2016). Demonstrating that the operations of a study such as the data collection procedures can be repeated with the same results, reliability was tested by repeating the case in other learning activities the researcher has carried out with two activities in different semesters and different groups. Reliability relates directly to the way evaluation is conducted.

This study included the consistency of the research procedures used in collecting qualitative data by maintaining records and taking notes constantly. Also, the study design applied for this case study carefully considered all three strategies: note-taking, immersion, and exposure to multiple situations—as recommended by Chatman (1992) to support observational consistency to ensure the reliability of data collection. Besides, this study included consistency in selecting participants who were considering engineering as a profession and have knowledge of traditional laboratory experience. It involved implementing other procedures associated with data collection during the activity: recording data, implementing participant observation notes, and in interviews where informants permitted note-taking, the field researcher-made careful observational notes throughout the session. With individual interviews, records of each standard were available to participants upon their request. Consistency of data in the study is achieved by cloning and replicating research by other researchers to draw a similar conclusion (Pitoura & Bhargava, 1995). Reliability can be authenticated through the corresponding input to validate cross-examination and measurement. Because this research was based on the supervisory team, a second interviewer monitored the time and financial implications, and because of the confidentiality of the interview, participants will not be compromised in any way (Carson et al., 2001). Instead, the researcher dealt with the interview data only with the supervisory team because confidentiality is an important ethical issue for interview participants. The current research findings substantiate what had already been found, but this is significant because practical, rather than theoretical, data was gathered through discussion and interviews with engineering students with experience in both collaborative learning and laboratory work. Besides, this study is interpretively validated through content analysis software for data analysis and then reviewed manually.

4.8.4 Internal validity

Internal validity is relevant for explanatory or causal studies only, and not for descriptive or exploratory studies. This study adopted a descriptive method which required probing questions, in-depth listening methods, and existing knowledge to develop the cause and effect links raised during in-depth interviews and considered important (Carson et al., 2001). Each interview had some probing questions to elicit additional details about issues such as: *"Can you describe the attitudes and approach to work of the other people working with you at the activity time? Tell me in more* *details? Did your experience on notice respect or disrespect happening in your group? Did you find a disrespectful situation while you were doing the activity? Can you tell me about it? What happens? How do you know? What did they say? What did they do?"* Also, in terms of internal validity, this study used the multi-stages approach to thematic analysis. This method was selected for its validity in generating rich data analysis and providing the reader with the necessary information to evaluate the quality of the research (Corbin & Strauss, 2014).

4.9 NVivo Software Analysis

The data collected from interviews were qualitatively analysed by NVivo software and Computer-assisted Qualitative Data Analysis (CAQDAS). Unlike ATLAS.ti and CATPAC, NVivo program design helps researchers in the analysis of texts to identify patterns in a large amount of data contained in the corresponding interview data and the dialogue between the participants during the activity discussion. Figure 4.2 illustrates the NVivo process from transcript interview until writing up the report based on the outcomes (Adu, 2013).

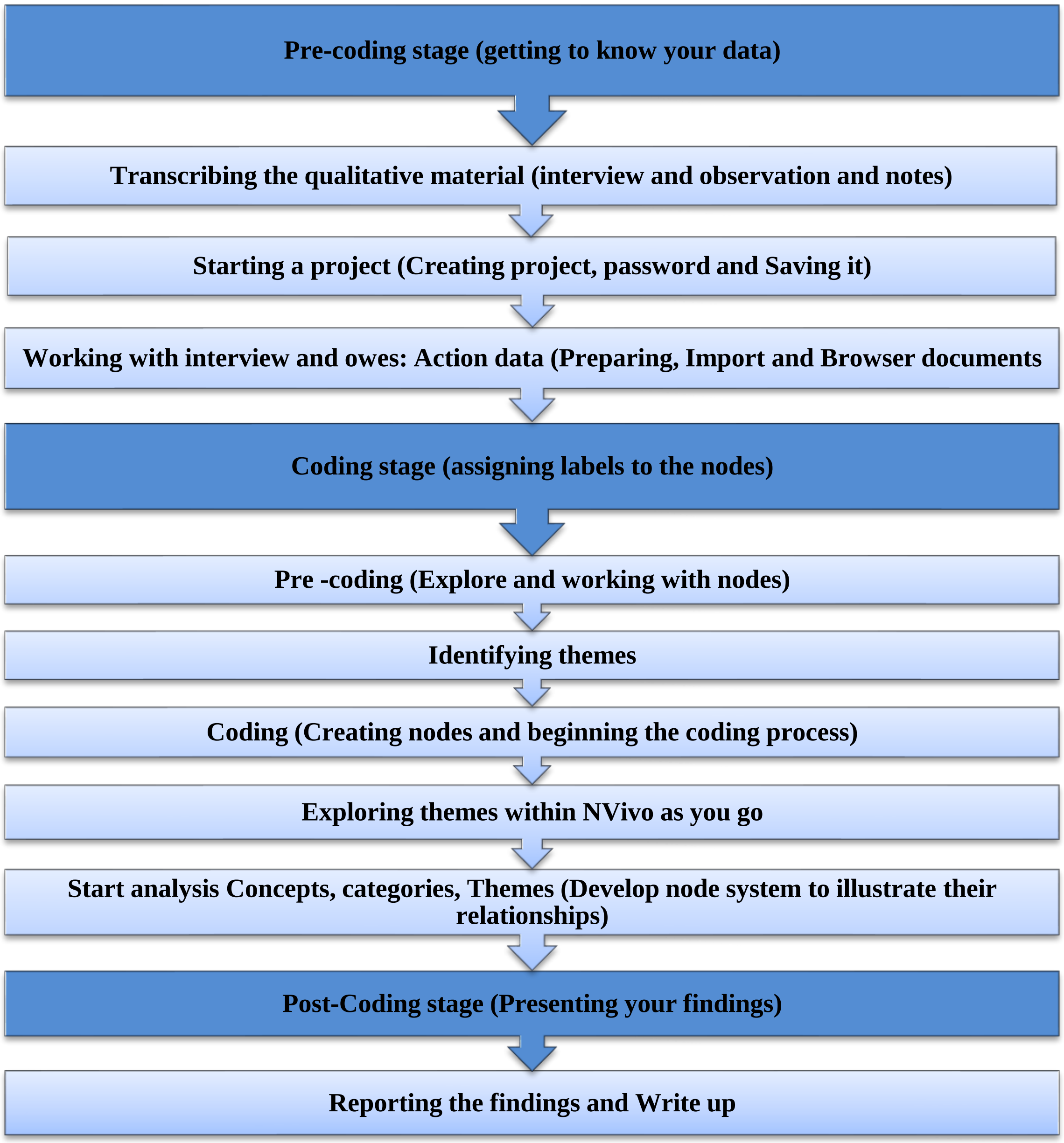


Figure 4.2: NVivo process developed by the researcher

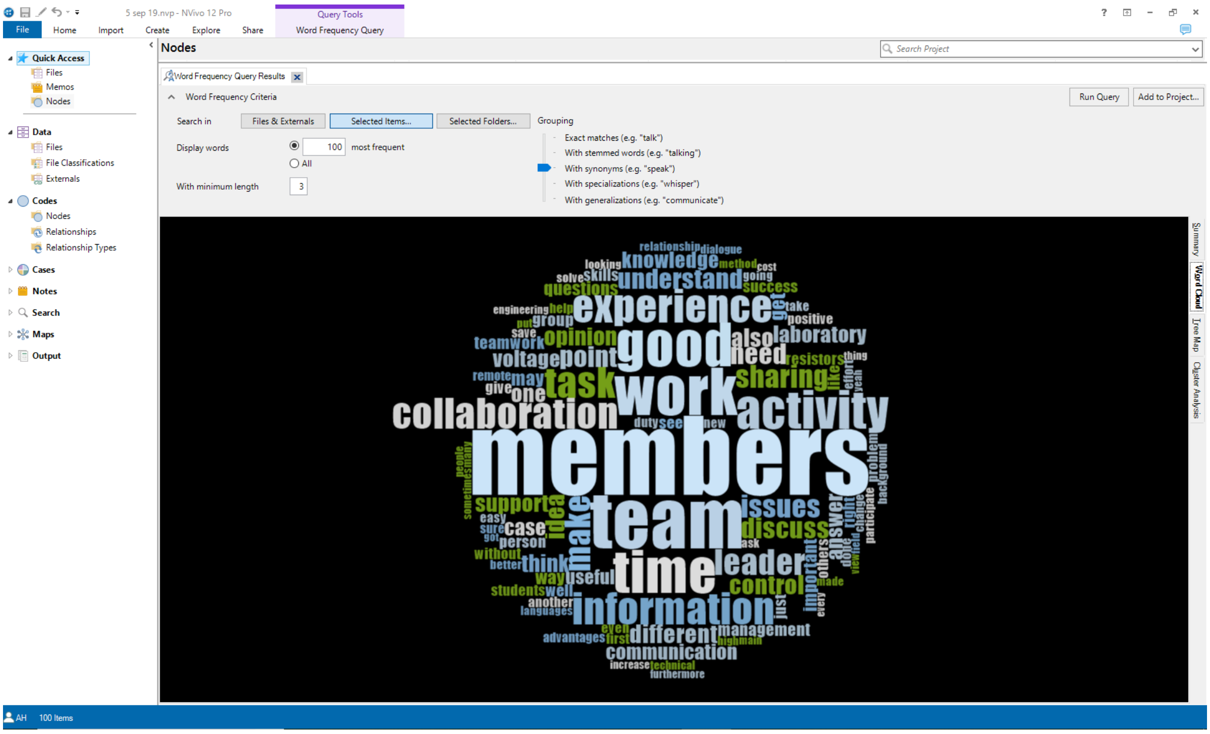
To ensure credibility, the researcher needs to be transparent in the coding process. There are three main qualitative data analysis phases that NVivo can use effectively to maintain transparency and achieve consistency in the labels or nodes created, and to achieve meaningful results with visual representations (Adu, 2013).

4.9.1 Pre-coding stage (getting to know your data)

- Transcribing the qualitative material (interview and observation and notes).
- Starting a project (creating project, password and saving it).

- Working with the interviews and observation data: Action data (preparing import and browser documents.
- Preceding (explore and working with nodes).

After the data has been transcribed, the coding process commenced reviewing all of the data for familiarisation. There was the ‘Query’ command (in NVivo), for example, which is a great tool to use to identify the kind of words participants use and how often they are used. Also, it can be used for the ‘Word Frequency’ result which could be displayed as a ‘Word Cloud’ with varied word fonts depicting the number of times the words are utilized: Data understanding or pre-coding follows (preparing documents for use and uploading external files). The encoding process began with the researcher becoming familiar with the process and reviewing all corresponding data and observation. The word frequency aspect also examined the concentration of particular words by participants. As a result, ‘word frequency’ can appear as ‘word cloud’ where the words that are repeated several times in a variety of mentions in the data or contain repeated phrases are discussed, as seen in Figure 4.3.



Search in: Selected Items...

Display words: ● 100 most frequent ○ All

With minimum length: 3

Grouping: With synonyms (e.g. "speak")

Figure 4.3: Word cloud

Moreover, in the query, it is possible to determine how a specific word or phrase can be used, or the frequency of the responses by the participants. Also, 'Text Search query' command can search for text and result in the creation of a ‘word tree’—as shown in Figure 4.4.

A word or phrases used before and after searching a word appears in the Word Tree helps to know the context in which it was used.

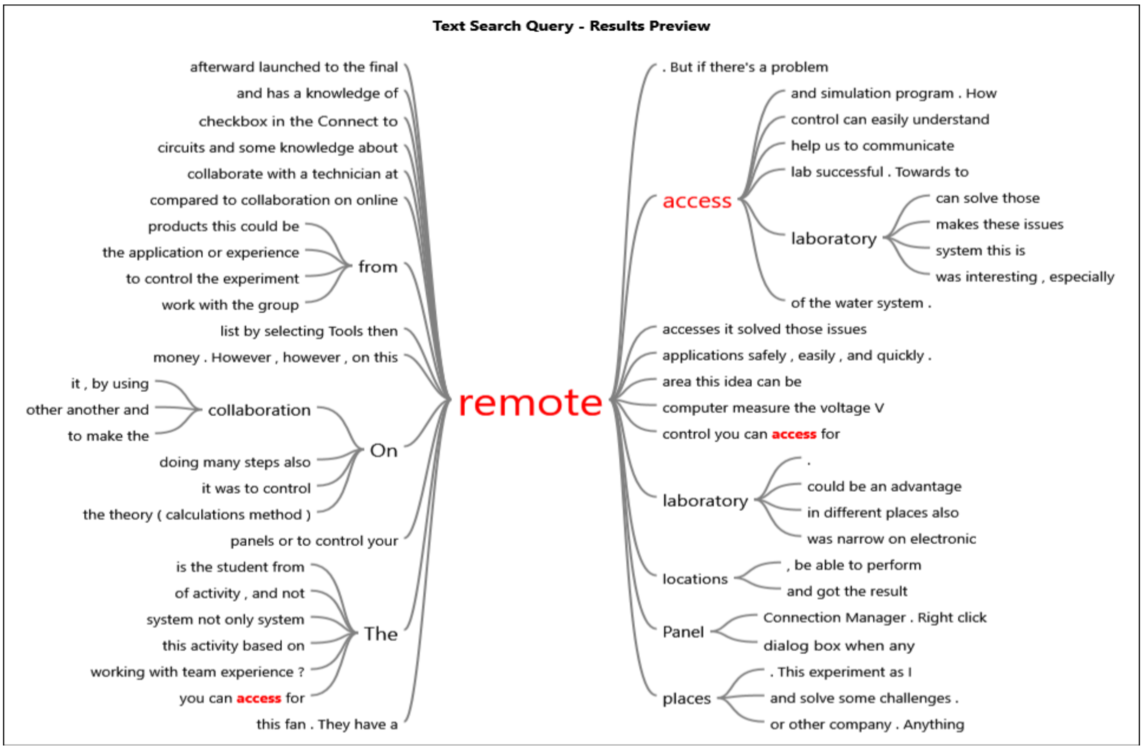


Figure 4.4: Word tree

4.9.2 Coding stage (assigning labels to the nodes)

- Identifying themes.
- Coding (creating nodes and beginning the coding process) (See Appendix H).
- Exploring themes within NVivo as you go.
- Start analysis concepts, categories, themes (develop a node system to illustrate their relationships).

When coding, the consistency of codes or nodes generated is very crucial (Adu, 2013). It helps to see the relationships between nodes easily and sometimes establish underlying ideas and meanings among them. It helps to easily see the relationships between nodes and parents' children node and determine underlying themes to understand the idea and meaning among them. Consistency of nodes can also help to organise the research question by creating labels for the nodes (Saldaña, 2015).

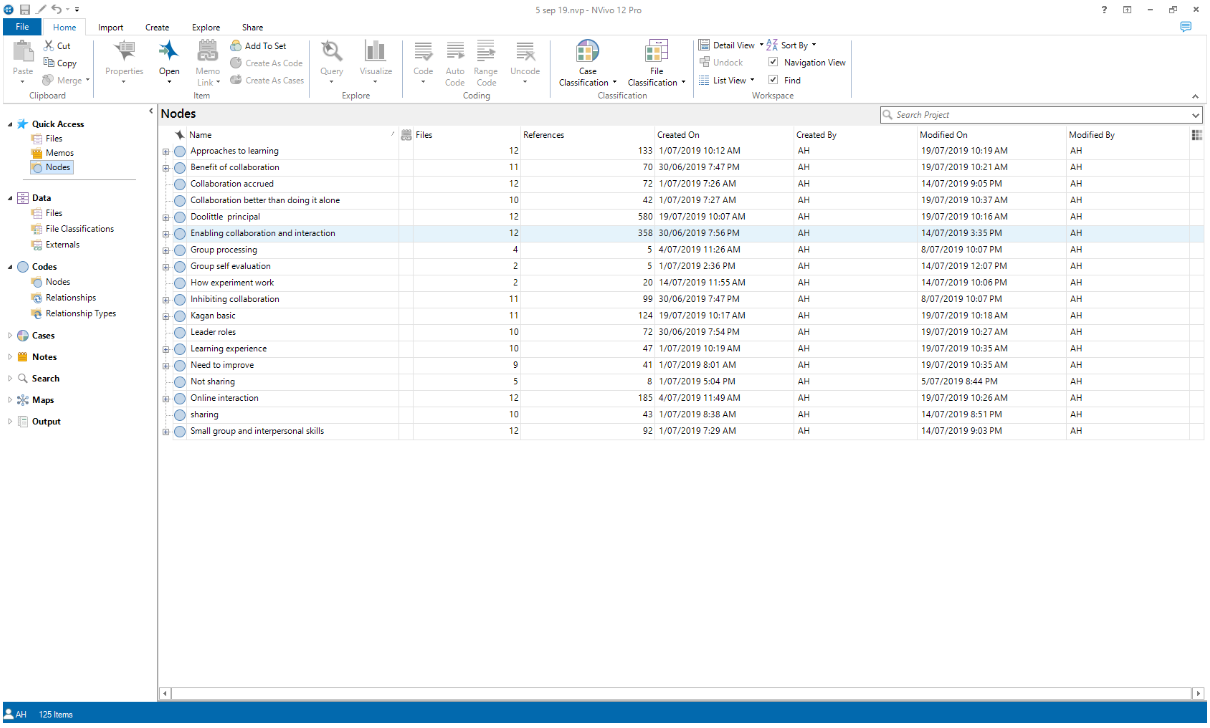
4.9.3 Coding phase

It was critical from the beginning of the coding process to sort the same information into the relevant nodes. The process helped the researcher to monitor the relationships between ideas and research concepts generated, and the meanings of each node (refer to Appendix H).

4.9.4 Explore themes

Data analysis was performed using the NVivo program, which helped the researcher to identify thematic, conceptual categories. The data from the participants' interview transcripts and activity recoding were coded, using a qualitative data analysis methodology program, NVivo 12, which supported the storing and manipulation of texts and documents; and supports the creation and manipulation of codes, known in NVivo as nodes (Gibbs, 2002).

NVivo was used to analyse interviews transcripts and recording session activity and select and aggregate them into data that can be coded into various nodes. Nodes can be names or labels for a concept or idea for data. Encoding text in a node is the process of establishing a relationship. NVivo was used to look at the raw data for themes, core topics and sub-themes (as shown in Figure 4.5).



Nodes

Name	Files	References	Created On	Created By	Modified On	Modified By
Approaches to learning	12	133	1/07/2019 10:12 AM	AH	19/07/2019 10:19 AM	AH
Benefit of collaboration	11	70	30/06/2019 7:47 PM	AH	19/07/2019 10:21 AM	AH
Collaboration accrued	12	72	1/07/2019 7:26 AM	AH	14/07/2019 9:05 PM	AH
Collaboration better than doing it alone	10	42	1/07/2019 7:27 AM	AH	19/07/2019 10:37 AM	AH
Doolittle principal	12	580	19/07/2019 10:07 AM	AH	19/07/2019 10:16 AM	AH
Enabling collaboration and interaction	12	358	30/06/2019 7:56 PM	AH	14/07/2019 3:35 PM	AH
Group processing	4	5	4/07/2019 11:26 AM	AH	8/07/2019 10:07 PM	AH
Group self evaluation	2	5	1/07/2019 2:36 PM	AH	14/07/2019 12:07 PM	AH
How experiment work	2	20	14/07/2019 11:55 AM	AH	14/07/2019 10:06 PM	AH
Inhibiting collaboration	11	99	30/06/2019 7:47 PM	AH	8/07/2019 10:07 PM	AH
Kagan basic	11	124	19/07/2019 10:17 AM	AH	19/07/2019 10:18 AM	AH
Leader roles	10	72	30/06/2019 7:54 PM	AH	19/07/2019 10:27 AM	AH
Learning experience	10	47	1/07/2019 10:19 AM	AH	19/07/2019 10:35 AM	AH
Need to improve	9	41	1/07/2019 8:01 AM	AH	19/07/2019 10:35 AM	AH
Not sharing	5	8	1/07/2019 5:04 PM	AH	5/07/2019 8:44 PM	AH
Online interaction	12	185	4/07/2019 11:49 AM	AH	19/07/2019 10:26 AM	AH
sharing	10	43	1/07/2019 8:38 AM	AH	14/07/2019 8:51 PM	AH
Small group and interpersonal skills	12	92	1/07/2019 7:29 AM	AH	14/07/2019 9:03 PM	AH

Figure 4.5: Nodes on NVivo

4.9.5 Post-coding stage (presenting the findings)

The aim of reporting the findings and writing up those findings is the primary purpose of conducting qualitative analysis to generate topics to address the research questions (Adu, 2013). After coming up with themes, the next stage is to present the findings.

4.10 Summary

This chapter provided the research methods followed in this study. A qualitative approach subsequent to the case study method was chosen as the appropriate research approach. The case study selection criteria were explained to justify the selection of specific cases. For this study, multiple data collection methods were incorporated, including the interview protocol as the primary source of data collection and documentation as a secondary source. Ethical clearance was obtained through USQ (Approval No. H14REA079). The invitations to recruit students via the study desk involved only a small number of students. Interviews and observation of students were used as the basis for collecting information considered necessary for this study. To establish the quality of the research design, four tests related to social research (construct validity, internal validity, external validity and reliability) were considered, and their application to the study was explained. Following the research approach, the research design was described; and a flow diagram of the data gathering process is presented in Figure 4.2 and provides an outline of the three stages that are followed in this study. Finally, regarding the data analysis approach in this study, multiple data analysis methods were discussed, including qualitative content analysis employing NVivo software. This chapter presented the research design and methodologies followed in this study and in the next two chapters the findings obtained from the various analyses are presented. In Chapter 5, the results of the qualitative data are presented; and Chapter 6 provides a discussion on the findings.

Chapter 5 RESULTS

The previous chapter introduced the research methodology that was designed to ensure data collection and analysis would allow the research questions to be answered. This chapter presents the results of the analysis of interviews conducted with each student in the research. These qualitative data were analysed to identify factors from the students' point of view that were believed to influence successful collaboration in RALs. The study explored the potential for value creation from collaboration in RALs by identifying factors that were perceived to influence the adoption of collaboration; including enabling, challenges, and issues of facilitating collaboration in a RAL. This exploratory method involved six face-to-face and four online interviews with the students who were all selected and recruited from the University of Southern Queensland. These ten participants comprised students from different language backgrounds, but the communication was in English as that was the language of instruction. However, in international collaboration it cannot be assumed that all people can understand each other even though they can all speak English, since cultural considerations and accents may have some influence; nevertheless, the makeup of this group reflected that of a typical cohort. In addition, the participants were diverse in that they were drawn from across the various engineering majors as a convenience sample (mechatronics engineering, civil engineering, construction engineering, electronic engineering, and electrical engineering). Assuring inclusivity for the research was discussed in Chapter 3. This chapter is divided into four sections. The first section reports on the student task reporting, the second section discusses the interview data. The third section presents the observation and the fourth section offers the activity of recording analysis.

5.1 Result of Activity Reporting Task

This section reports on the collaboration in RALs activity and the processes the students were required to undertake. It discusses and report the activity, including the sorts of comments the students made during each step, the student task (Appendix A) and leader task (Appendix B). During the activity and video recording session, the students were given a task sheet (refer to Appendix A) The introduction of the task sheet refers the student to trigger and provide links to web sites to access to the activity and software and are directed to follow the instructions. Initially, they have to check the voltage divider task by following the instructions as shown in the diagram in the task sheet, and the experiment which has been created in LabVIEW. Moreover, the voltage divider circuit is already connected and written in LabVIEW. It can be accessed through the link during the period of activity because the relationship can be different every time:

In the electronics and electrical engineering field, the voltage divider is a simple but the most important electronic circuit, which splits the input voltage to comparative across each resistor in series and the amount of voltage across each resistor, which is used to change the high voltage to a small voltage. Therefore, higher resistance will have a higher voltage drop across it, while the smaller resistance will have a lower voltage drop across it. Here, the output voltage is part of the input voltage and should be less than the input voltage. The current through the resistor circuit is shared among all series resistors. In this activity, the input voltage relates to three resistors in series that result in the input voltage divider being divided into three outputs voltage. When the input voltage is applied across all three, the resistor and the output voltage will appear from their relationship.

The leader must verify that each student has the right access to the link. It also asks participants to follow the instructions (see Appendix A and Appendix B) in the sequence of activities and write notes in the spaces available for all tasks and talk to colleagues in the group to check answers with each other and write the correct answers.

The voltage divider circuit is made-up on LabVIEW and power with voltages between 0 V and 100 V. The voltage (resistors R1, R2, and R3) has been connected and can be controlled and monitored for each resistor with a voltameter.

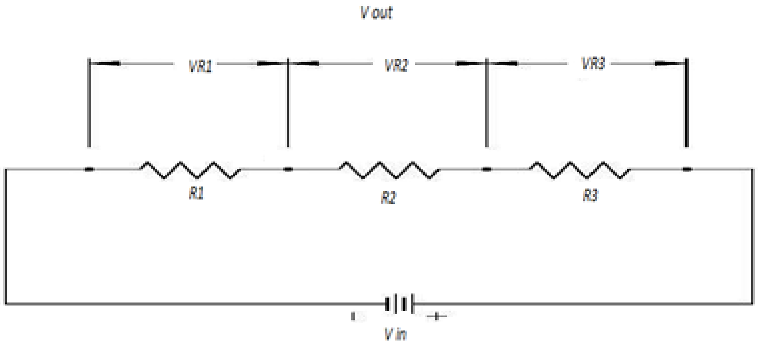


Figure 5.1: Voltage divider circuit

The voltage divider circuit shown in Figure 5.1 contains three resistors, *R1*, *R2*, and *R3* connected in series via input voltage (*Vin*) with different output voltages (*VR1* via *R1*, *VR2* via *R2*, and *VR*3 via *R*3) to become (*V out*) and will appear to cross each resistor in turn concerning individual resistance values and provide a different but smaller value than the input voltage. Resistors in series contact have the same current, but the different voltages drop across them as individual resistance values will generate different voltage drops across each resistor.

By applying the input voltage between 0 to 100 volts from the knob it will be monitored on a digital display as a digit, and analogue voltmeters as shown in figure 5.5 are also the output voltage that can be observed across each resistor with a number of analogue voltmeters.

The student has been asked to make sure that the voltage divider is working correctly by making sure that the voltage across each resistor is increased and decreased according to the individual resistance values. When moving the knob with the mouse, as shown in Figure 5.2, the student can then observe fluctuations in output voltage on the voltmeter screen. In other words, this is achieved by changing the input voltage of the knob up and down by computer mouse or keyboard and monitoring the voltage across each resistor. The voltage difference between the three resistors varies from 0 to the maximum voltage on each resistor. In this case, there are three essential output voltages: *VR1, VR2,* and *VR3* on this circuit that contain a series of three resistors, as shown in Figure 5.2. The resistors turn a large voltage into a smaller one depending on the level of voltage crossing resistance by using three resistors in series connection and input voltage, then the output voltage, which is smaller and part of the input voltage.

After students have become familiar with the activity and use of the program, they are asked a question in step 6. During the activity session (refer to Appendix N), students commented on the task questions.

Most of the students perceived that the voltage divider worked well for them. For example:

6. Does the voltage divider appear to be working at this point? Why?

Participants (R02) (Leader) and (R04) said the following in response to Question 6:

Yes, because when we have changed R1, R2 and R3 and we got the different values of VR1, VR2, and VR3 (R02; Leader)

Yes, the circuit is connected with series resistors, and the current is similar. Is the voltage divided by putting a different value of a resistor? (R04)

The responses of participants are available in Appendix N.

Also, during the activity, students were asked to calculate both the maximum and the minimum amount of voltage obtainable from this potentiometer circuit (as measured between the wiper and ground) as shown in Figure 5.2. Students had the same response on minimum value Zero and output voltage, but others were slightly different on amounts of maximum, because each student had their trial and the resistor may not be of the accurate amount, so each student had a slightly different amount in their responses to this question. A snapshot of calculations by participants M07, R04 and N06 are shown in Figure 5.3.

7. R2=3.3k Ω and R3=1k Ω as shown below. Calculate both the maximum and the minimum amount of voltage obtainable from this potentiometer circuit (as measured between the wiper and ground):

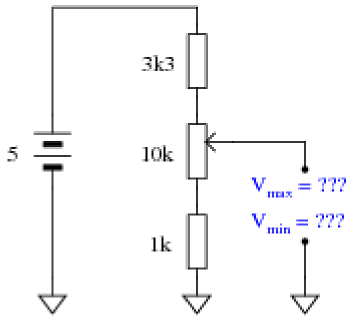
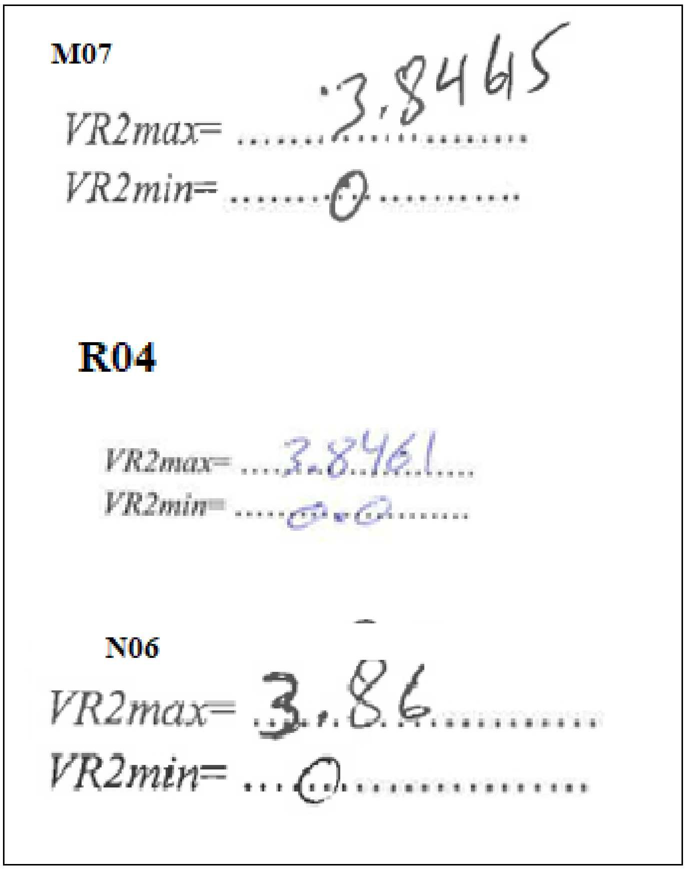


Figure 5.2: Voltage maximum and minimum



M07

VR2max= 3.8465
VR2min= 0

R04

VR2max= 3.8461
VR2min= 0.0

N06

VR2max= 3.86
VR2min= 0

Figure 5.3: Student report

Since students can manipulate the variables software system and come up with an accurate result compared to the calculation result, this means the students understand how to manipulate and observe what is going to happen in the activity. It also provides them with the ability to use the equipment and feel like they are working on a real activity accurately. Their ability to do this indicates that students are interpreting how to use equipment because if they cannot show the amount accurately then it indicates they do not understand how to manipulate the pieces of equipment. When this is so through the collaborative learning approach they can then benefit from the knowledge of other students and get back on track. This demonstrates that the software can be a teaching model that can contribute to collaboration in RALs.

5.1.1 Collaboration between students

In the next step students calculate both the maximum and the minimum amount of voltage that each of the voltmeters will register, at each of the potentiometer's extreme positions. The leader's role involves scaffolding student learning, for example, when the leader has asked the student to do a specific task questioning takes place between the student and leader and/or a conversation can ensue between students themselves.

This provides opportunity for the sharing and co-construction of knowledge and ultimately effective collaboration.

The following provides an extract of a conversation that shows how following the instruction to "student connect the potentiometer (variable resistor) figure 3.4 in the circuit by setting percentage 0%, 25%, 50%, 75%, and 100% positions, the output voltages are obtained (measured with respect to those percentage" the participants tried to clarify what the settings meant. The leader directed a question to help them focus on the core task. The students' responses show evidence of them questioning (Y01), agreeing (R04), explaining and predicting (Y01) and confirming (S09, R02) in arriving at a joint conclusion.

> *The leader (R02) said "I want to see it" (referring to the Monitoring Student Progress).*
> *Moreover, Y01 asked, "So does that mean the circuit is set if it is showing 25, 50, 75, and 100 per cent positions?"*
> *Another student, (R04) agrees, Okay. Okay. Oh, yeah, yeah.*
> *Y01 explained: . . . "which means now it is 2, like the other resistors there must be getting the same. Yeah, I was. Yeah, and we can predict the other ones like for example, the 75 per cent are the same".*
> *Next student (S09) confirmed, "Ten by fifth is fine".*
> *Furthermore, the leader (R02) responded and also clarified, "Yes, fine."*

Thus, student R04 collaborated by agreeing with the leader R02, and Y01 collaborated by explaining the unclear information. Also, S09 collaborated by offering a new idea and seeking more clarification, while the leader agreed with the team members' and provided clarification.

Similarly, with analysis after the student finished, the task started with discussion and analysis about the question, and the students shared their thoughts about the experience:

> *We can start the analysis with of some of us sharing our opinions about this experiment. So, what do you think? (M07)*

In addition, the students shared a summary of their LAB work and some of them viewed the activity as a refreshment of knowledge because of the positive experience, and its suitability for monitoring by experts and the supervisory team, with the sharing of results and discussion. These views of it being an excellent and enjoyable experience are evidenced by the comments below.

> Share your thoughts about your experience doing this experiment:
> *It is a good refreshment of my information about the electrical circuit. (R04)*
> *It is suitable for remote learning because the supervisor can control the value and show the student the result. (Y01)*
> *Good idea, sharing the same result and discussion the outputs can give me the bright face of using the technology overseas. (O010)*
> *It’s a good program: (N06)*
> *For me, it is an enjoyable experience by doing this and by sharing the test with another person. (R05)*
> *It taught me to control the voltage and resistors from my remote place. (S09)*

The students enjoyed a constructive experience in relation to the task and gained an understanding of the idea. This contributed to showing that the activity and collaboration were successful and enjoyed by participants in the context of collaborative learning in RALs. It also resulted in their understanding of the Voltage Divider circuit as a result of the learning experience.

The students were asked to describe the stages of the Voltage Divider, and its functionality and then compare answers with their colleagues. Most of them mentioned their understanding of voltage dividers, as shown in the following dialogue.

> List 2 stages of the voltage divider and describe their functionality; then compare your answer with your colleagues.
> *One explains the voltage divider to show how the voltage is divided into three resistances. (Y01).*
> *Input voltage and resistances and monitor. (R04)*
> *The voltage divider can give power to other devices. (N06)*

Moreover, from the task equation, the students were asked how the Voltage Divider is used to divide voltage. In other words, thy were asked if it can be used to generate any voltage from an initial, more significant voltage, by dividing it? They were then asked to discuss this aspect with their colleagues and ascertain how they would know that the system was working well without any faults. Thereafter, students held talks and discussion with at least two colleagues to hear their point of view and summarise the outcomes. The activity was an authentic, natural process, and the variables could be controlled by watching what happened to the output of voltage, as well as comparing the calculation and measurement value.

> How is the voltage divider used to divide voltage: in other words, can it be used to generate any voltage from an initial more significant voltage by dividing it?
> *For me, we can put any values of resistance, and we see what happen to the voltage, and everyone can see that from his computer at the same time. (R05)*
> *By comparing the amount of the voltage of each resistance with the manual solution. (M07)*
> *By comparing the values of the voltage of each resistance with the manual solution, if it has the same amount, so the software is working correctly. (Y01)*

5.1.2 Students' self-report on their learning and collaboration

With regards to students' self-report, each team member needed to check with the other members and then respond. Their responses and interactions in terms of collaboration show it to be successful with the technology found to be easy to use and helpful in simplifying their learning. The participants also mentioned that when the task became practically more difficult regarding the circuit connection, unclear figures made the collaboration more interactive, because some of the figures needed to be calculated from the minimum and maximum resistors, as shown in Figure 5.4 regarding participant R05. Unexpectedly, students need to discuss and work out the solution before starting to manipulate the resistors online. Sometimes a student did not understand the example and needed to learn how to make the resistors as minimum or maximum as shown in this figure. This process gave the students the confidence to ask and discuss these factors, which enhanced their collaboration during this time.

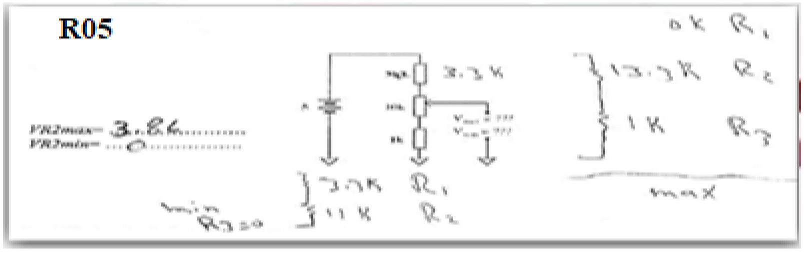


Figure 5.4: Calculating the minimum and maximum resistors

> *R05 noted that: "When the figure was difficult to understand the questions were helpful and the collaboration helped to clarify."*
> *"The collaboration was successful". (S09).*

> *M07 agreed with Y01: "The zoom software plus live chat, and the internet connection, was simplicity to learn and made it easy to work out the different values".*
> *N06 commented: "the strategies involved effective communication, controlling the task, fast gathering of results, and monitoring the system; and the challenges were recoding the results in the database, using the multi-interface screen to use the system widely".*

Further, the students made their evaluation and reflection for the collaboration session as follows:

> *The skill must learn on this activity was different control devices by the internet and working as a team (Y01).*
> *And about the collaboration has replay explaining for others who are not familiar with the topic.*
> *Furthermore, another student (S09) reported it was a good experience and he attained new knowledge to use new software and control an experiment by software, and regarding collaboration he noted that it was easy to work in collaboration with others.*

The section on the student report task sheet helped the researcher to check for collaboration in a real situation; and also helped to formulate the interview questions, and ensure the research validity by triangulating it with the interview and observation data.

5.2 Result of RAL Collaborative Experience

The students participated in two, 2-hour sessions that provided Remote Access Lab collaborative learning experiences using Zoom software. These sessions were structured in terms of roles and responsibilities where one student was designated as 'leader' and had the responsibility of managing the session according to a written guideline (see Appendix B). This section provides details of this RAL collaborative experience by first providing information about the leader's role and, secondly, the extent to which the students collaborated. It does this through samples of the conversations that ensued in relation to task demands, and the scope of the software. Finally, the section discusses evidence for the RAL collaborative experience in relation to its ability to meet the principles of learning experience design for collaborative learning as outlined by Doolittle (1995).

5.2.1 The role of the session leader

The leader reminded the students of the purpose of the research project and how the tasks were designed for them to gain Lab experience through remote access from off-campus any time anywhere. The leader role was supported by a guideline. The students were also advised that the learning experience was intended to be team-based and collaborative with the opportunity to raise and discuss issues and ask questions as they may arise. They were each provided with a ‘Student Task Sheet’, and the leader explained the connection between the tasks and how the computerised Lab software program was able to be used to fulfil the learning objectives. He noted for instance, “So you can see that the input voltage is here at the side of the big button”. “This is the total voltage; here you can see it's divided into three - called the resistors or knobs”. “There is another three-volt voltmeter”. The students’ understanding of the procedure was also supported by the content of the task sheet as it provided instructions for the procedural activities and included spaces for them to write their observations. The leader noted, “We're going to write what we observe in the spaces provided”.

The students were advised to discuss aspects with their colleagues in the group as they carried out the tasks, which involved working out the answers and checking with each other to record their responses/answers. The leader explained how the software worked, including reference to both the computer screen and hard copy as shown in Figure 5.5, and advised in the first instance ‘to play’ with the software to get a feel for how it worked and so encouraged their initial exploration:

> *It's easy; you just switch to them to control them. So, two of us can get to play with the diagram or the program while others observe and then change . . . Okay, if you can just send something.*

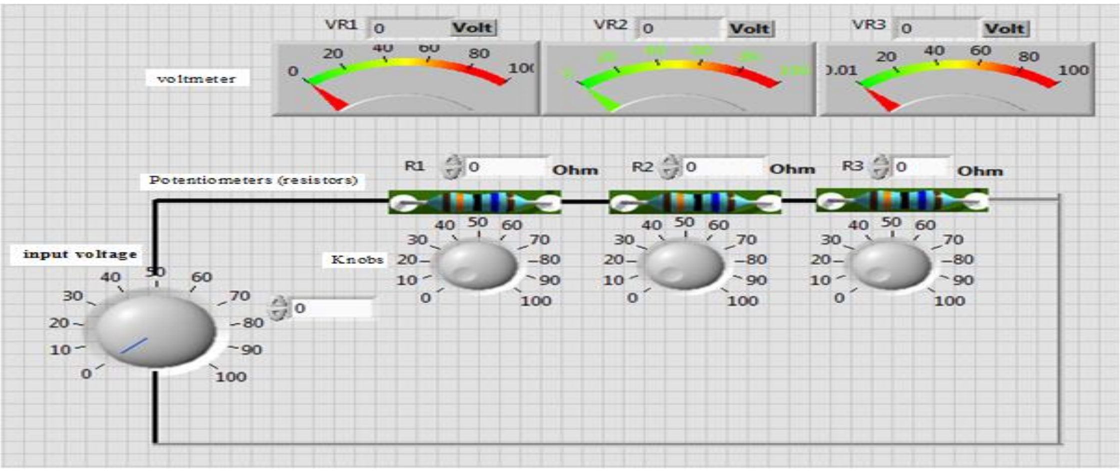


Figure 5.5: Display of front panel online provided on supporting material

The leader further explained, for example, as follows:

> *So, as you can see here the power with the voltage between zero to 100 . . . also is going to be the control . . . Okay, so as you can see this here, it's from the entire bowl with the voltage between zero and 100.*
>
> *Once a resistance R1, R2, and R3 have been connected, as you can see here. I'm going to increase its resistance with the voltmeter, which is above there to ensure that there is power. So, this is the first point I think—you have to make sure that there is power there.*
>
> *So now we apply an input voltage drop between 0 to 100 volts. We have the right if you can't control the total voltage to play using the knob to input and there will be a monitor on the node and digital numbers beside the knob as in the diagram in your handout, so.*

By applying the input voltage between 0 to 100 volts from the knob the students saw it was monitored on a digital display as digit and analogue voltmeters, and as shown in the circuit it was also the output voltage that could be monitored across each resistor with a number and analogue voltmeters. They were able to experiment with the software and test out the manipulation of other variables, which is evident in the following interaction between two students:

MO7: Monitor the output with the digital voltameter so whatever you get - put here. I think the mains voltage. Yes, you can see here it is increasing now. It's 44 - the same, it’s 60 now.

M010: Yep! It's 100.

M07: You can put any amount on the resistors any amount and observe it.

M010: The total I can see. It just became good.

M010: Yes. It depends on the material of the resistor.

(Y08): The value of resistors.

(R02): (Leader): The total is going to be 100.

> *So then check that the voltage divider works correctly by doing the following (demonstrates) to ensure that VR1, VR2 and VR3 voltages across this resistance are still operating. That is on the front panel. So, it's working; as we can as see that it's working normally, and has almost hit if you're going to get the total, you're going to be 100. So, if you reduce the. . . (The leader asks Y08 to read): Can you reduce a little bit - changing to 70 or 80, just to make sure that it's working perfectly?*
>
> *My question in terms of the resistances - you can play on this as well. But any amount whatever, what's the relationship between those R1, R2, and R3 amounts and the resistors?*
>
> *M010: Yes. So, I think every resistance here has capacity and can handle a specific amount of voltage. So, if you increase the capacity of the resistor, you can adjust contribution and handle the voltage as much as the others. So here* R1 is 1000 *Ohms and you can see the voltage of all resistors . . . that resistance is 64.8 volts - easy.*

To further explore the nature of the collaboration an audit of the vocabulary in use in students' interactions was conducted. Table 5.1 provides an overview of the various terms that make reference to experimental terminology such as control, compare, change the value, vary, observe and monitor, besides indications of measurement: larger scale, frequency, maximum, minimum, proportion, and limitations, In addition, the vocabulary provided insights into the verbal tasks as in explaining, discussing, describing, sharing ideas.

Further to this, Table 5.2, provides an overview of the scope of this key language use in relation to students' collaborative dialogue ensuing from their RALs learning experience. The sample dialogues show that the dialogue involved (1) instructions, (2) questioning (both by the leader and participants), (3) opportunities for inquiry and clarification, (4) evidence of experimentation and (5) evidence of discovery. Then three exemplar tasks are presented in Figures 5.6 to 5.10 to provide details of the activities from which these dialogues derive, demonstrating the collaborative nature of the learning experience as opposed to the traditional isolated LAB experience that is typically monologic rather than dialogic (Habibi & Dashwood, 2020).

Table 5.1

Vocabulary in Use in the RALs Learning Experiences

1. Change the voltage	16. Explaining	31. Proportion
2. A useful method but larger scale	17. For example,	32. Reduce
3. Challenge	18. Frequently	33. Resistor
4. Change the value of the resistor	19. Implement this software's devices	34. Safety
5. Communication	20. Indicate	35. Save time
6. Compare	21. Leader	36. Sequence
7. Control	22. Limitations	37. Sharing the ideas
8. Control for example	23. Location	38. Software
9. Control the circuit	24. Maximise	39. Strategies
10. Describe functionality	25. The maximum amount of voltage	40. System
11. Diagram	26. Maximum and the minimum allowed	41. Team member
12. Difficulty and issues	27. Minimal	42. Values

13. Discussing	28. Monitoring	43. Vary
14. Example	29. Observe	44. Vocabulary

Table 5.2

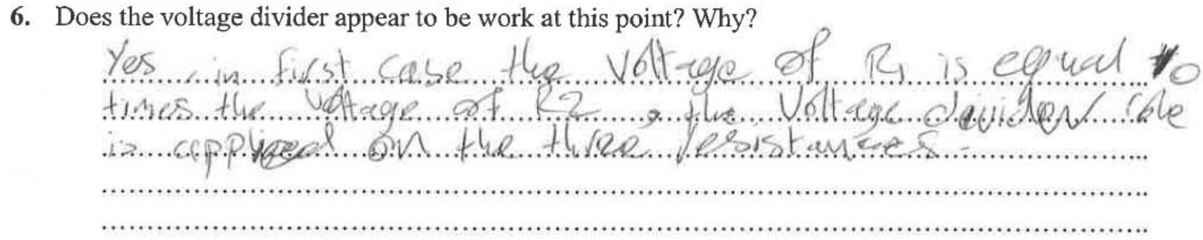
Overview of the Scope of Key Language use in Students' Collaborative Dialogue

Language use	Sample dialogues
Instructions	Just click on the front panel and then release the control. Follow the diagram. Try to question why it's working. So why is it working? I think it's working because each time it got different values when we put the different resistances in for each. This is the resistance- we got different values.
Questioning	So, the first thing is solving that total and then how are you going to swap this one? So, I just have a question. Can we just apply two controllers at the same time? No, because if it is the same as a real experiment you can control only once. Who has the control now? Okay, so just before did you get the answers for the Question 7?
Evidence of experimentation	So, whatever your input 'here' is going to appear in there. The total summation of the VRs should be the same total voltage. R02 (Leader): This is quite interesting. If you are looking at the project and you are working together and each one has a good idea that means if I get an idea I wanted to show the results so I can apply my idea and then give it to you as a controller so you can apply and you can observe together with the results. I think that's a good thing. So, yeah. *M010: Regarding distributing the voltage. Distributing the voltage on the terms of the resistors. How about if we just connect this resistor in different ways like on each other like yeah, parallel so the voltage is going to be the same at each resistor?* *So that means R1 is 10 times R2. So that means if this one is 20 and this one going to be two this one is zero.* *All right, which is it?* *I don't know. This one is R1, 2 times R2, and R3 is equal zero, so, yeah, it's working here if I want the same value of R2 to so easy if you just put in the number e.g. 12.* *Okay, it's working now to 25.*
Evidence of discovery	*Oh yeah, I got it, this is voltage, and this is ohms* *This is obviously the voltage for 3 resistors.* *I think they will not make a point if you've got some experiences with different voltage, different ohms, you know, that means you can do your experiment and I can do mine.* *There's no problem because it means the maximum fifteen points three kind and so many of us are working.*

Task One

The students were required to complete the answer to the following question on their record sheet: Does the voltage divider appear to be working at this point?

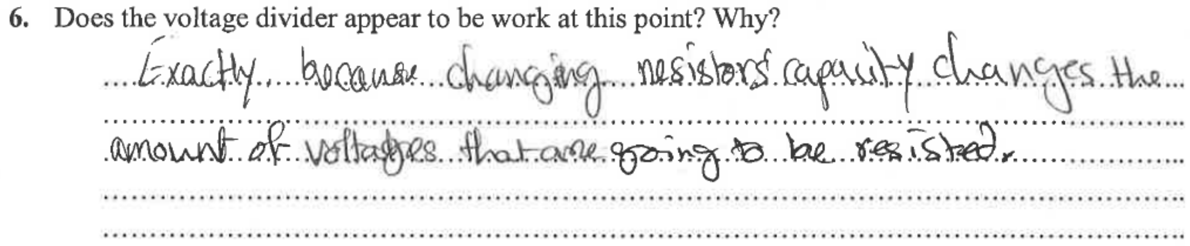
Yes, in the first case the voltage of R1 is equal to 10 times the voltage of R2 and the voltage divider is applied to the three resistances.



6. Does the voltage divider appear to be work at this point? Why?

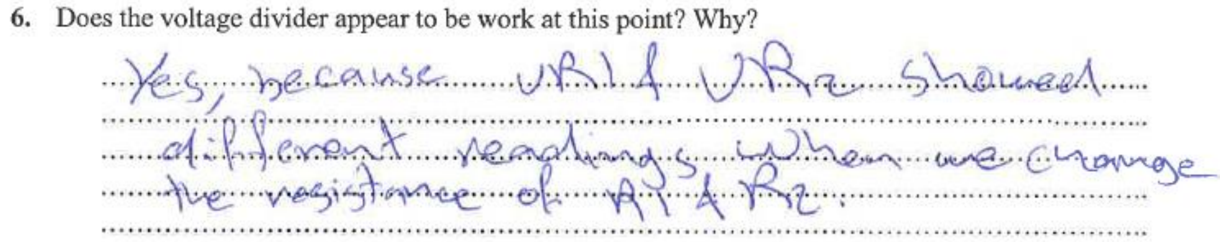
Yes in first case the voltage of R1 is equal 10 times the voltage of R2 & the voltage divider rule is applied on the three resistances.

Exactly, because changing the resistors' capacity changes the amount of voltages that are going to be resisted.



6. Does the voltage divider appear to be work at this point? Why?

Exactly, because changing resistors capacity changes the amount of voltages that are going to be resisted.



6. Does the voltage divider appear to be work at this point? Why?

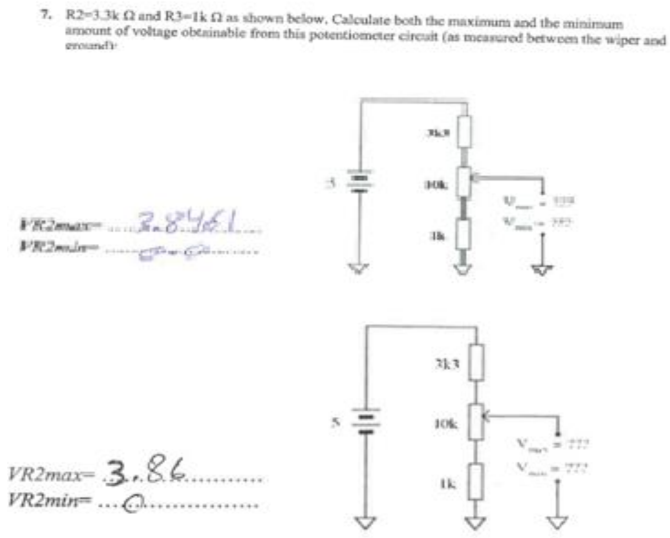
Yes, because VR1 & VR2 showed different readings when we change the resistance of R1 & R2.

Yes, because R1 and R2 showed different readings when we changed the resistance of R1 and R2.

Figure 5.6: Students' answers

Task Two

Another question provided data for R2 and R3 and required the students to calculate the maximum and minimum amount of voltage obtainable from the potentiometer circuit as measured between the wiper and ground (Figure 5.6).



7. R2=3.3k Ω and R3=1k Ω as shown below. Calculate both the maximum and the minimum amount of voltage obtainable from this potentiometer circuit (as measured between the wiper and ground):

VR2max= 3.8461

VR2min= 0.0

VR2max= 3.86

VR2min= 0

Figure 5.7: Students’ answers

Leader advice

The maximum case should be 3.8.

The minimum case is 0 volt.

The variable resistor on extreme positions: so, the first resistor is 1K and the second one is 5K. The third one is 2.2K, and we need them to calculate both the maximum and minimum amounts of voltage that each of the voltmeters was registered at each of voltmeters monitor as shown in Figure 5.7. Can you take the video controller now? (Student sketched details on task sheet).

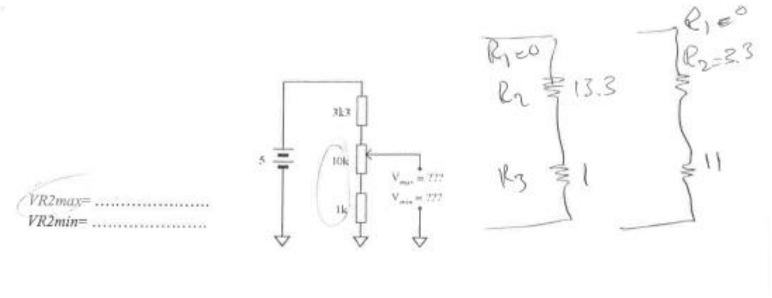


Figure 5.8: Voltage divider circuit

Sample dialogue

R02 (LEADER): Switch controllers. Yeah.

Y08: 2, 2 yes. We are. One map. We must add 1 and 5 to 6 equals and the other three equals to 1/2. This is the We Are One maximum, which is 1.24.

R02: (Leader): Which wanted to bring to restore question here to 1?

Y08: Point

Y08: Two four

M07: I got the same reading.1.4 Yeah, which is also we are three minimums. It's VR1 maximum. The three, you know is a 3.75. It's 345 yep.

Y08: So far six, when we change the variable resistor appeal for the resistance number two to the minimum, is the value for r 1 will be 1.

Y08: There 2 value will remain to zero the R3 three so we will add five to two point two eight seven.

M010: So, we VR1 minimum may be equal to VR3 maximum here, you are right.

R02: VR1 minimum. Yep, should be equal to VR 3 maximum, which is true. Yeah.

Y08: no not the same R1 is the minimum value and R3 1.7 Yeah1, 7 and VR3 is the maximum value which is 2.5

R02 (Leader): Two nine it's okay

R02: Let's go to the nine.

R02: 9 when R3. What would happen to the voltage across the resistance R to when R1 becomes 1-time R2?

Y08: So R3 equals zero R1 equal 1 time, for example, our one's 1 R 2 is 1 11 33 so can you do that? Doesn't say so.

R02: Okay and R2.

R02: 53 So they both resistors R1 and R2 are the same amounts.

M07: Is this it?

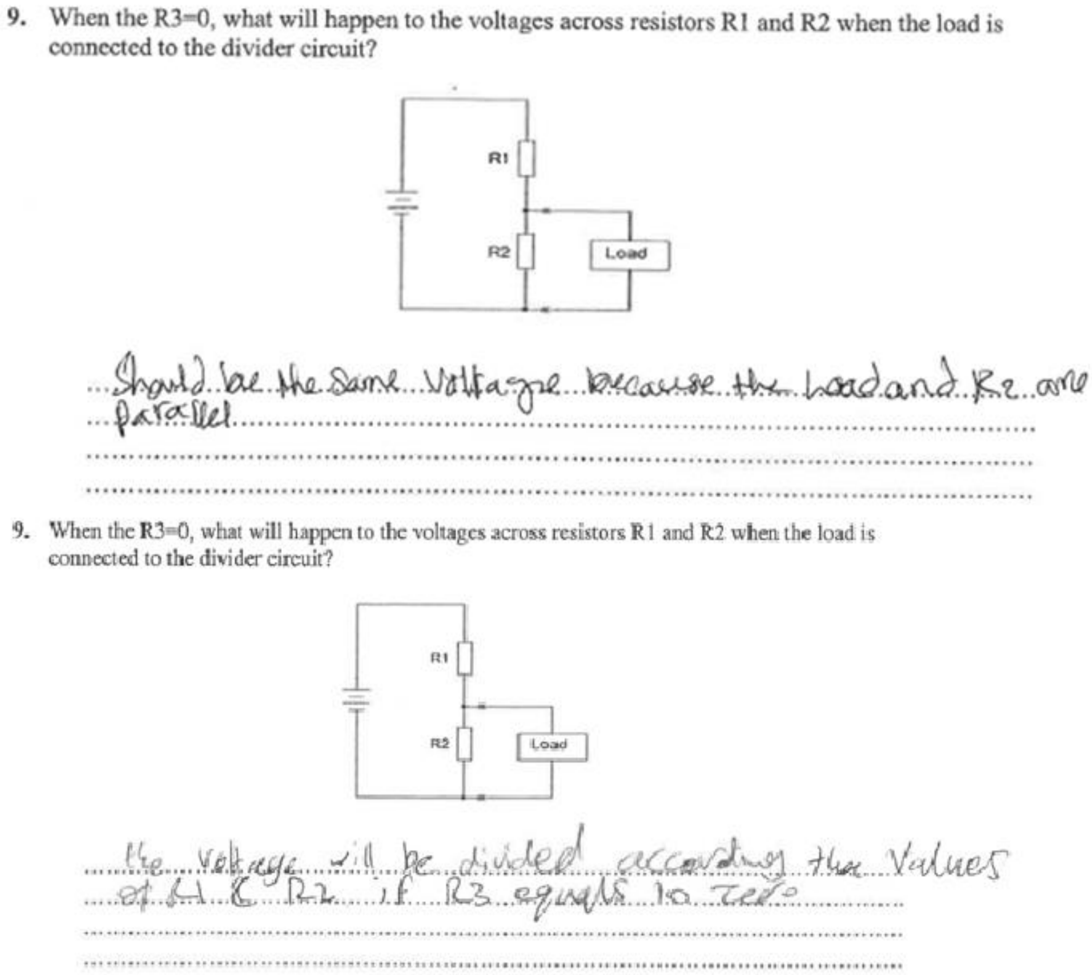
R02: (Leader): What will happen to the voltage across the resistor R1 and R2 the root is connected to the divider circuit.

Task Two

Students were asked: “When the R3=0, what will happen to the voltages across the resistors R1 and R2 when the load is connected to the divider?”

Written answers stated as follows:

- Should be the same voltage because the load and R2 are parallel.
- The voltage will be divided according to the values of R1 and R2 if R3equals zero.



9. When the R3=0, what will happen to the voltages across resistors R1 and R2 when the load is connected to the divider circuit?

Should be the Same Voltage because the Load and R2 are parallel

9. When the R3=0, what will happen to the voltages across resistors R1 and R2 when the load is connected to the divider circuit?

the voltage will be divided according the Values of R1 & R2 if R3 equals to zero

Figure 5.9: Voltage divider circuit with load

R02: (Leader): Should R2 to be the same voltage? Why?

Y08: Because they're are in parallel.

R02: (Leader): When R1 is 5K.

R02: (Leader): Potentiometer (variable resistor or change the resistor)

R02: (Leader): R3 and R2 are equal in this circuit…two is zero per cent 25 per cent 5 percent, simple the output voltage depends on the resistor's percentages.

R02: (Leader): So, the following output voltages obtained measures with (voltage between two points as shown in Figure 5.8 above R2 point and other point is ground) respect to ground.

R02: (Leader): R1 is 5k

R02: (Leader): And I had to prove you finished voltage on R2 and R2 equals so that means (the voltage across resistors are same voltage) 2 & 3 actually, yes.

Y08: Now we will put the potentiometer to the position of zero per cent so the second one is 25 per cent now 5 per cent and then 75 percent.

Task Three

The final task question required students to analyse their activity, continuing to explore in more depth asking "When the R1 = 5 kΩ potentiometer R3 and R2 equal zero in this circuit is set to its 0%, 25%, 50%, 75%, and 100% positions, calculate the output voltages obtained (measured with respect to ground, of course)". As shown in Figure 5.9 first amount of:

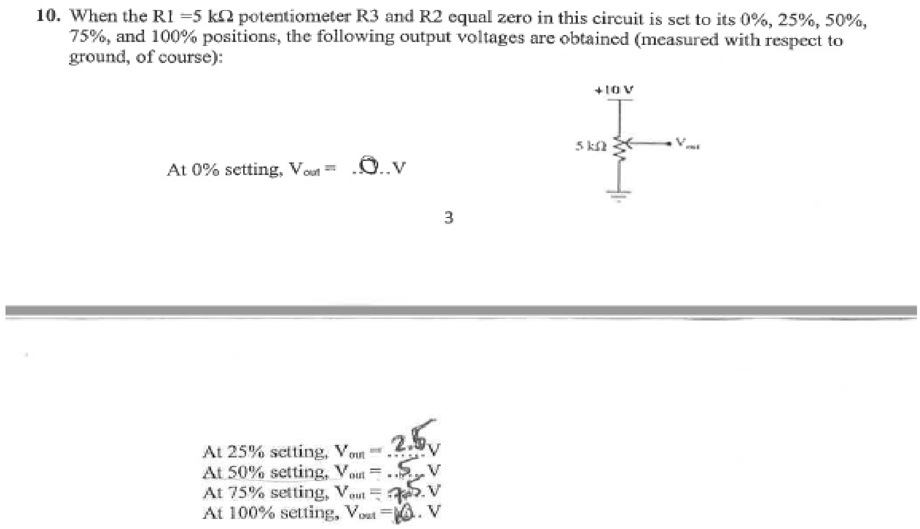
When 0% R1= 0

25% R1= 1.25 K Ω

50% R1=2.5 K Ω

75% R1=3.75 K Ω

100% R1=5 K Ω



10. When the R1 =5 kΩ potentiometer R3 and R2 equal zero in this circuit is set to its 0%, 25%, 50%, 75%, and 100% positions, the following output voltages are obtained (measured with respect to ground, of course):

At 0% setting, V_{out} = .0..V

3

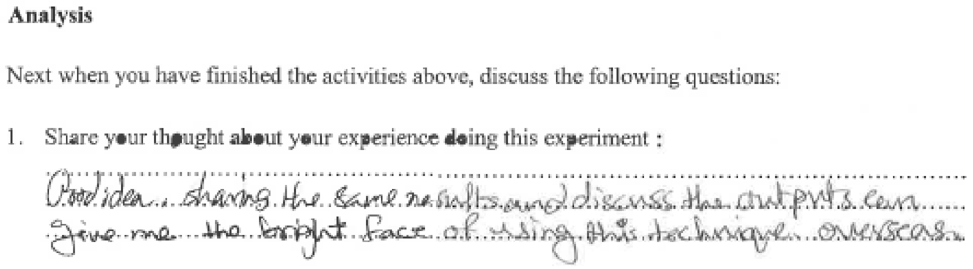
At 25% setting, V_{out} = ..2.5.V
At 50% setting, V_{out} = ..5..V
At 75% setting, V_{out} = 7.5.V
At 100% setting, V_{out} =10. V

Figure 5.10: Voltage divider circuit as Potentiometer

M07: We can predict the other ones like, for example, the 75 per cent is to put one and the same.
M010: Ten by fifth is fine.
R02: (Leader): Yes fine.
M07: We can start the analysis of some of the group. Share your thoughts about this experiment. So, what do you think?

Students' responses*:*

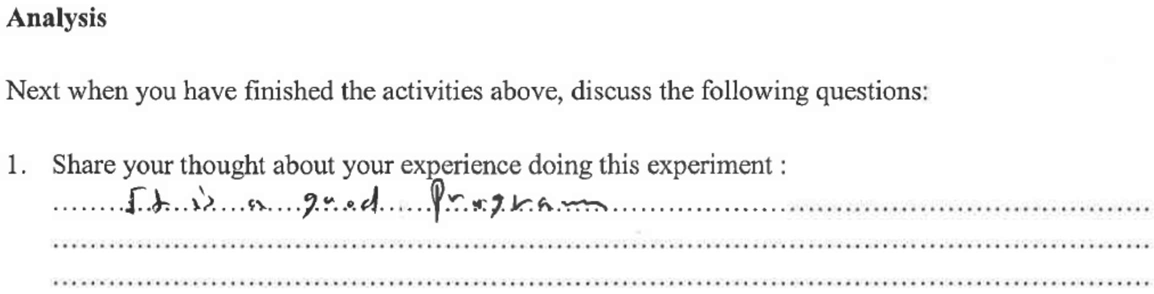
- *Good idea. Sharing the same results and discussing the outputs can give me the bright face of using this technique overseas.*
- *It is a good program.*
- *It is good for remote learning because the supervisor can control the values and show the students the results.*



Analysis

Next when you have finished the activities above, discuss the following questions:

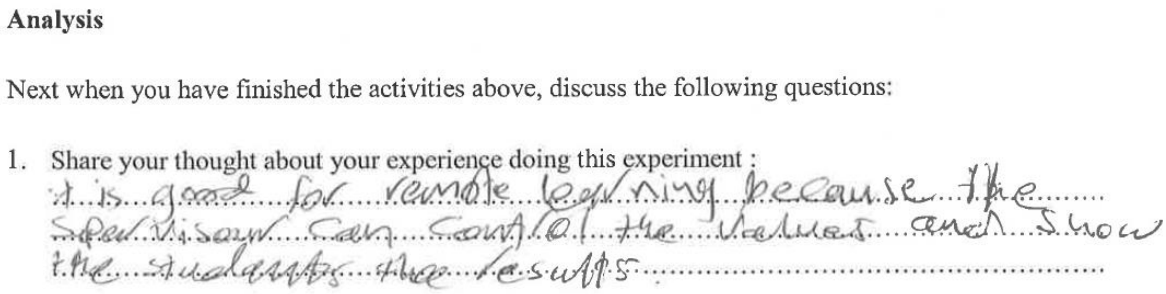
1. Share your thought about your experience doing this experiment :
Good idea.. sharing the same results and discuss the outputs can
give me the bright face of using this technique overseas.



Analysis

Next when you have finished the activities above, discuss the following questions:

1. Share your thought about your experience doing this experiment :
It is a good program



Analysis

Next when you have finished the activities above, discuss the following questions:

1. Share your thought about your experience doing this experiment :
it is good for remote learning because the
supervisor can control the values and show
the students the results

One student in the role of leader reinforced the collaborative experience stating as follows:

> *This is the meaning of collaboration…sharing knowledge. This is the main point. And the good thing is we have discussed these tasks so you will know the application of the Voltage Divider through sharing. It helps deal with many difficulties and facilitates you talking face-to-face and working together with me*. (R02: Leader)

5.2.2 Summary

In summary, the learning experience through the RALs showed students adapted to the process that facilitated the collaborative approach. The dialogue that ensued showed that they were able to explore the Voltage Divider equipment presented online and 'play' to explore how it worked. They were able to experiment and manipulate the variables to solve the problem presented, and work out relationships. The task involved them both addressing and discussing critical questions and interpreting data to demonstrate their understanding and fulfilment of the assessment.

5.3 Result of Student Interviews

The following sections report the results of the analysis of ten student interviews, where the emerging themes derived from the application of NVivo are reported. This is followed by an explanation of their relevance to the research focus on Kagan's PIES – the four outcomes of collaborative learning: Positive independence, Individual Accountability, Equal Participation, and Simultaneous interaction and Dillenbourg's (1999) theoretical elements of collaboration learning (situation, interactions, learning process and effects). As well the third theoretical aspect of Doolittle's (1995) eleven principles of learning experience design that foster a constructivist approach to collaborative learning are tested to explore the extent to which the students engaged collaborative in their RALs learning. As discussed in the methodology section, the thematic analyses related to these three theoretical bases, which were used to structure the reporting of the results.

5.3.1 Learning Situation

The learning situation or context includes the contextual feature of students who are generally at the same level regarding their knowledge and skills, and shared common goals in working with each other. It includes students' perceptions about collaboration and collaborative learning in the RALs context, which is one of Dillenbourg's (1999) collaboration learning elements. Themes related to:

- Factors to be considered as enabling collaboration and interaction in RALs.
- Factors to be considered as inhibiting collaboration in RALs.
- Differences.

5.3.1.1 Factors to be Considered in Enabling Collaboration and Interaction

As a result of the analysis of the interview transcripts using NVivo, seventeen principal factors emerged that participants identified as enabling their collaboration and interaction with each other during the RALs learning experience. These are presented in Table.5.3. This table was developed by using Matrix Coding Query NVivo software by comparing the student frequency of talk about the factors that enable collaboration among participants.

Table 5.3

Proportion of Students Identifying Factors Considered as Enabling Collaboration Based on Frequency Counts

Enabling collaboration and interaction	%
Leadership	90 %
Preparation	90 %
Student level	90 %
Technology	80 %
Familiarity of topic	80 %
Relationship	70 %
Student's Task	70 %
Culture and background	70 %
Time	70 %
Questions	70 %
Experience	70 %
Languages	60 %
Trust	60 %
Difficulty and undefined information	50 %
Interesting topic	40 %
Fun environment	30 %
Incentive	20%

As shown in Table 5.3, the factors most frequently mentioned by participants (between seventy and ninety per cent) were Leadership, Preparation, Student level, Technology, and Familiarity of the topic. Each factor is discussed in turn below.

The presence of *Leadership* was identified as one of the most significant factors that required consideration for enabling collaboration and interaction. Ninety per cent of the sample agreed that leadership was a central influence on enabling collaboration during their remote learning activity. This is reflected in the following interview responses:

> *The leader was particularly helpful at the beginning of the activity when I encountered some information about the task. I was utilising the leader to keep me on track. If there was no leader, I would have struggled a lot, because I asked the leader at the opening time, and he simplified these questions. Additionally, skills may affect collaboration in my case. I had better-heard others before I give my opinion maybe because I was not sure about my idea. (M07).*

> *The leader was good at controlling the time and dialogue and encouraged the members to participate. (Y08).*

The importance of *Preparation* was also highlighted by ninety percent of the interviewees. The team being well-prepared was seen as an essential element for enabling the collaborative learning in RALs. In raising this issue, the interviewees included the importance of them being able to trial the access and equipment/software, participate in training and use the resource material. They saw this as necessary to facilitate the collaboration and learning in the context of the remote learning experience. This is evident in the following selected interviewees' responses:

> *The difficulty the team has been facing needed training more than once to reduce the gap between the team members. Some of our team members took a long time to do their duty because they were not familiar with the communication tool and poorly skilled in this aspect, they needed to be trained before the activity, which would make the improvements on their performance. (S09).*
>
> *Previous preparation for the task helped me to participate more, if I don't know the team member before the activity, the beginning of the activity may result in low collaboration, because the team members need to know each other and their thinking before starting in the lab, then the conversation will start. (Y08).*

Student-level as a theme emerged in relation to the importance of participation and the need for students to have the requisite level of skills and knowledge to enable them to collaborate and interact with each other in a constructive way. Again, mine out of ten participants raised this issue as necessary for their active collaboration in the RAL activity. This is borne out in the following comment from one participant in particular:

> *The procedure (activity task) is an essential factor in which to make the steps more comfortable. For all members and in same orders from the first of activity till they get the result and the activity objectives, in case of all team members, sit on the same page and the same request. (R05).*

With respect *to the theme of Technology*, the students highlighted the reliance upon technology-based communication in this trial of RALs as a crucial consideration. This included using Zoom CLOUD technology, LabVIEW software, the need for the Internet, and the simulation machine. In addition, they pointed out that this was vital aspect of the collaborative learning experience upon which they depended, and it required participants to have prior knowledge and skills. One of the technical aspects was *dealing with the conference tool (ZOOM software).* The conference tool was the principal critical factor to enable the collaboration because participation required the use of the video and audio technology, and for composing text as a communication tool. This is evident by the fact that eighty per cent of the sample raised this issue, as indicated in the following interview responses.

> *The communication tool Zoom software made the collaboration more comfortable, because this activity was based on the remote laboratory in different places; also, it delivers real dialogue and debate. (R05).*
>
> *Also, if there were unclear points, there were life and voice communication conference tools available, and you can ask any members if they have finished their duty. (Y08).*
>
> *I want to comment on the communication process and the instruments since it can facilitate circulating the information among the participants, and that makes the process clearer and faster. (O03).*

Similarly, *Technology availability*, was highlighted as an important issue in terms of Internet access being identified as one of the essential factors upon which the collaboration in RALs depended. Combined with the availability and accessibility of technology, this and the quality and speed of the Internet was raised as vital to success. This is indicated by the following participant's response.

> *Internet connection (or intranet) should be available with high quality to make the process easier. (O03).*

Technology as creating '*reality'* was also raised in relation to the remote access laboratory as an issue. The participants mentioned that creating the 'real activity' had been fulfilled through the use of technology, thus achieving realism. They viewed their ability to interact and share information as replicating a real communicative experience, sharing through human senses but via RALs. Supportive comments on this aspect include:

> *The video-audio communication gave the activity a sense of reality. A human can be transferring the information throughout their senses if the work is correctly done. (S09).*

> *The idea came to me about controlling the devices remotely and collaborate with other team members after I had done it. I like the idea very much because I felt it was like real and everything., I have done it and I have seen it with other team members . . . and we did not imagine this technology and how it feels like the authentic experience. (Y08).*

In addition to the feature of enabling collaboration on RALs, *the familiarity of the topic* emerged in terms of the participants having prior information and knowledge in the same field. Familiarity with the topic was seen as increasing students' confidence and contributions, and maximising their efficiency. Thus, there is a need for adequate preparation, because it contributes to making the collaboration successful. So not surprisingly, eighty per cent of the respondents stated that *familiarity of the topic* was one of the most significant factors that must be considered for enabling collaboration in RALs. This is supported by the following comments by participants:

> *My point of view, if the task is related to my field, I will contribute more also I will be an active member of members for the activity and maybe be a leader if I see myself easily relating to this task. (O010).*
>
> *The maximum efficiency of this activity needs to be all members from the same background and the same major not randomly from a different background it may be successful but not the same as with the team members from the same backgrounds and major. (M07).*
>
> *If the team members have the same level of theoretical background and the same field, the efficiency will be high, and the rate of error will be meagre, those will reduce the time, effort and cost and also the leader's efforts. (O010).*

The following section presents a further nine factors that emerged from the comments from 60-70% of participants. These were *Relationship, Student's Task, Culture and background, Time, Questions, Experience, Languages* and *Trust*.

Some participants expressed *Relationship* as one factor that has an impact on collaboration. Approximately seventy per cent of the sample indicated that the relationship between participants is one of the essential elements to be considered when planning collaboration in RALs. Participants said that a good relationship could increase the success of the collaboration, especially once they overcame any shyness and made friendships—which ultimately make the activity more comfortable. Comments on this aspect include:

> *Yes, because if the member's team has a good relationship will increase the success of collaboration and made the activity more accessible. (N06).*
>
> *The relationships between team members I knew some of them before the activity during the study at university and others, I have known them during the activity and collaboration then we became friends. My relationship during the activity was good; each team member helped others if there are any issues or point not clear about the task. (Y08).*

Besides, seventy per cent of the sample highlighted that *student task* was an essential factor in helping participants be in the same order making, and that more communication and attraction was required to consider collaboration in RALs. They stated several reasons why they believed that the student task should be considered when adopting it.

> *The student's task helped us to be in the same order and on the same page (M07).*
>
> *The procedure (activity task) is an essential factor in which to make the steps more comfortable. For all members and in same orders from the start of the activity till they get the result and the activity objectives, in case all team members stay on the same page and the same request (R05).*
>
> *The precise task makes the collaboration accrue and makes more communications and interaction between the team members. The task may support the collaboration of team members who have the level of understanding and follow the task or have good experience on something similar to this activity; this will help to make the collaboration possible, and this experience may be able to occupy him/her as a leader (R05).*

Seventy per cent of the respondents stated that *culture and background* were significant factors that must be considered for collaboration in RALs. Students noted that a having a mix of peers from different cultural backgrounds could increase the knowledge of other team members and their perceptions of the task as well as how they think. It was thought that those with a diverse background can understand the same information but apply a different problem-solving method that might allow such team members to assist more often and therefore increase collaboration. It was also pointed out that students from the same cultural backgrounds could also help increase team members communication and cooperation.

> *We were from the same backgrounds and cultures that helped us with communications and more collaboration (R05).*

The advantages of learning with peers from different cultures and backgrounds was also reinforced as helping to make the collaboration work more effectively by the following comment:

> *There were different nationalities, but this thing made the collaboration work more, and some of the team members had a good experience and theoretical and practical knowledge. This also supported the collaboration and working as a team, . . . some team member had few experiences and needed some help from other team members to have done the job correctly (Y08).*

The students also identified *time* as an essential factor when considering teaching in RALs and using the collaborative approach to learning. Seventy per cent of the sample agreed that time affected their level of collaboration. There were two aspects of time that emerged, which were ‘time zone’ and ‘time management’.

The *time zone* should be considered when the activity needs the task to be performed successfully, as participants need to meet at the same time (synchronisation) despite differences in time zones worldwide.

> *Choosing a suitable time to carry out the task successfully was essential due to the different time zones of the group members (R04).*

With regards to *time management* it was noted that the more carefully the equipment, task and learning activities were managed the better the collaboration was able to be facilitated; more benefits were perceived as ensuing because of time saved in the activity running without compromise. It was noted that collaboration also depended on team members managing their time to take notice of more than one point of view. The following comments emerged on this point:

> *I remember something which should generalise to the whole process - to have more managed and instrumented collaboration, as with this the more benefits you can get. (O03).*

> *The most essential point I have noted is if the time was restricted, I pointed out that only 50% of the objectives had been achieved, I had done 45min of an hour of course, but the rest of the time would go without any focus on the task, and I lost the rest of the benefit of the activity. (O010).*
>
> *The most thing I liked on this activity was improving the probability of managing time and dialogue, and previously preparation, because it was issued for teamwork; also when all members knew the aim they had met for and the functional purposes that needed to be achieved during the collaboration, the discussion and dialogue was easy and saved time and effort and there was high efficiency because all members knew what their responsibility was and other responsibilities of others, and not just predicting what was subsequent. (O010).*
>
> *The collaboration was possible when team members managed their time to take more than one point of view, letting team members solve the problem by any available method. (R05).*

The students also confirmed that the *leader* role in the collaborative learning approach that was adopted played an important role in managing time. This role was seen as essential to facilitating the collaboration activity. Also, one of the duties of the leader was to reduce the burden of how to go about learning together amongst the team and in contrast provide direction and support in scaffolding learning. Selected students comments below provide evidence of this view:

> *Also, the leader . . . was essential in this collaborative activity because s/he managed the time, and the questions and answers, even when there was a misunderstanding or different opinion, the leader went to another method to solve the differences by supporting the more correct idea or making suggestions to ask another team member to provide his/her advice to develop more understanding, and another view more explicit - and maybe the team member accepts the leader's opinion or gets another new idea. (R05).*
>
> *Also receiving each team member's point of view and the group leader completing their responsibility was a positive point, and it made the group reach the optimum solution with many points' views being discussed in excellent time. At this time the leader became the principal person in managing*

> *the time, giving each member the right to talk and participate in adequate time, and listen to his/her opinion on the issues; also if the team member was unsure on any point the leader gave his assistance to the remaining participants. (R05).*

The students also raised the issue of *questions*, seeing them as another critical factor that was essential to consider when designing collaborative learning in RALs. Seventy per cent of the participants perceived the role of questions to be an indispensable factor in assisting, revising ideas and gaining new knowledge by having to think and provide answer. It also assisted with a team focus to questions and to improve thinking and opinions as well as increasing discussion, thus, demonstrating collaboration was occurring. Participants' comments on this aspect included:

> *The work was outstanding, and the team member was collaborating well which means we got the new fresh ideas, sometime during the activity discussion and asking questions from all members we got the new novel ideas; by answering those questions we could get a good collaboration and working team talent. The original concept and knowledge helped me to discover more and more. (N06).*
>
> *Some of the team members asked questions for clarification if their thinking was okay; this helped all team members to focus and draw attention to the issues involved and improve their ideas and opinion. (S09).*
>
> *I preferred working as a group because there were questions, I could not understand, or if I needed more clarification from another member who was able to clarify; I benefited from their experience. (Y08).*

Additionally, seventy per cent of respondents referred to participants' past *experience* as having an impact in adopting a collaborative approach to learning in RALs. For instance, they believed that participants should have 'enough experience' and 'knowledge' to manage new technology in order to successfully collaborative. It was shown that those interviewed believed their collaborative learning activity was positive and helped them to perform well. The level of cooperation was seen as high and so helpful in making them feel more comfortable, so resulting in stronger collaboration. This was also seen as making the duties of the leader's role easier and in making the task more understandable. Some comments relating to this aspect include:

> *Some of the experience and contribution and clarification coming from the team made the activity more comfortable and understandable. (N06).*
>
> *The experience we bring can affect the possibility of collaboration, so this was essential for building the team. (R05).*
>
> *The thing that made the collaboration easy was the team members excellent skills and experiences, so we could share and receive the knowledge. (S09).*

Language use in the RALs collaborative learning approach was also identified by sixty per cent of interviewees as one of the essential factors to consider. They pointed out the importance of participants having a common understanding of the language of instruction and that used to collaborate in making the learning experience comfortable and logical. However, it was also mentioned that for those with English as an added language and previously a foreign language when they were challenged with new scientific vocabulary and processes even though they were successful they would have felt more confident collaborating in their own language. This was also a new pedagogical approach for these students. This view is supported by the following statements:

> *If the students' language is good enough, the collaboration will be secure in going, and the result will be more accurate. (N06).*
>
> *In any place, if you can depend on the mother languages, the collaboration performance and outcome will be the best. (S09).*
>
> *If the activity was in my mother language it would have been more comfortable and faster than using English for me. (Y08).*

Looking at collaboration from the perspective of relationship building sixty percent of interviewees raised the importance of *trust* being another factor essential when considering whether to adopt a collaborative approach to learning in RALs. Trust and creating a bridge of trust and mutual respect between participants can encourage the exchange of ideas. This makes it easier to share, discuss and solve obstacles and so better enable collaboration to be realised. This was explained in the following selected comments:

> *I trust them [peers] to guide me to an accurate solution. (M07)*
>
> *Build trust and a strong relationship between students. Relying on other people builds trust, and teamwork establishes strong relationships with students. Trust yourself enough to trust others. Innovation requires breaking down the old rules of thought and creating new ones. This means each member of the team must become more transparent than ever before. (Y01)*

In addition to the factors dealt with so far, the remaining four factors were raised by half of the group or less. Firstly. Five participants raised the issue of *difficulty and undefined information*, whole forty percent were concerned with whether it was an *interesting topic,* thirty percent the *fun environment* and only twenty percent on the issue of *incentive* to learn. However, even though a minority of participants raised these factors they are cannot be denied as vital to ensure the collaborative learning experience is successful for students.

Firstly, if students have *difficulty* in any way and have to contend with *undefined information* this can be a serious barrier to the implementation and the flow of the learning experiences. Students need clear instructions and learning materials that make the task explicit, which in this research the leader's role played a supportive part. The learning design attempted to ensure through the instructions and leader's role students would grasp the concepts and have opportunity to ask for help. Similarly, it attempted to engage students at the optimum level of their ZPD. Thus, fifty per cent of participants referred to experiencing difficulty and undefined information, which they resolved by being encouraged to work with peers in a collaborative way. Insights from these students are provided below.

> *The difficulty and undefined information encouraged me to get involved with other team members to make discussions wealthier, so at times I observed their answers to make sure that I had the concept. If this hadn't been the case, I wouldn't have been able to go toward the front 10 %. (M07).*
>
> *When the activity was hard, there was more need to collaborate, and team members were more active when more clarification was needed regarding the task. Sharing knowledge with the group has advantages for collaboration, especially when there is a difficulty or missing information. The support from other team members can cover what's missing. Furthermore, if each team*

> *member shares their data, it will be more than a 'one-point' point of view on the same issue and information exchange will be quicker. (S09).*

The importance of the topic being interesting to students was uppermost for forty per cent of respondents as they saw this as able to help foster the collaboration in RALs. They saw the choice of topic as being able to increase positive behaviour and the possibility of collaboration, as well as fostering successful results. This view is supported by the following comments:

> *An interesting topic and decisive argument may help ensure positive behaviour and make the collaboration more possible. (N06).*
>
> *An essential part was the interesting task and it was fun to get the highest available results. (O03).*

Again, related to motivation for learning collaboratively thirty per cent of the interviewee sample raised the importance of having a *fun environment* to increase collaboration. Participants said that interesting environmental activities could be time and cost-efficient, making collaboration more possible and increasing team members' attention.

> *To make collaboration possible, there needs to be fun environmental activities, especially when the time was long and there was a boring time during the activity or start with reasonable easy discussion to attract the team members. (R05).*
>
> *A fun atmosphere was there to get rid of the uninteresting and attract the team members' attention to the activity. (Y08).*

In addition, twenty per cent of respondents emphasised the importance participants having an *incentive* to learn. They perceived this to be an essential element for all members, and that supporting knowledge and providing social facilities would help contribute to successful collaboration. The following comments related to this aspect.

> *The incentive depends on the task type . . . in this case, the instructions and the experiment worked well to activate all members and the assistance was most supportive to help knowledge and foster social facilities. (O010).*
>
> *The moral support was an essential factor in keeping me involved and making collaboration successful. (O010).*

> *Incentive to participate and make collaboration successful can be achieved by giving the team members high marks for more involvement or for who can meet the right objectives faster than other groups. (R05).*

5.3.1.2 Factors that may inhibit collaboration

Through the analysis of the interview transcripts using NVivo six factors emerged which the participants perceived as inhibiting collaboration, and which negatively affected their learning in their attempts to collaborate in RALs. They saw them as inhibiting their interaction with each other during the RALs learning experience. These factors are presented in Table 5.4. This table was developed by using Matrix Coding Query NVivo software and compares the frequency that the participants referred to this inhibitor in their interview dialogue.

Table 5.4

Factors Inhibiting Collaboration

Inhibiting collaboration	%
Technology	100 %
Time	90 %
Languages	80 %
Unfamiliarity with the topic	80 %
Leadership	60 %
Relationship	40 %

As shown in Table 5.4 the most significant factors that inhibited collaboration in RALs were technology, time, languages, unfamiliarity with the topic, and leadership. While 80 to 100 percent raised the first four inhibitors, sixty percent highlighted leadership and forty percent relationship (the lowest percentage).

While *technolo*gy was also recognised as a positive, participants' perception of it as an inhibitor referred to the reliance on conference tools and the CLOUD (e.g. Zoom) as well as LabVIEW software that in turn depend on access to the Internet requisite technology and the need for communications expertise. This definition of technology was often based on students need for essential knowledge and skills because the whole activity depended on technology to connect, and the RAL depended totally on the technology being available. All participants stated that this was an essential factor to consider if moving to learning in RALs. They found that it was difficult to use the program without their completion of the setup session. As well they experienced delays in the process of communication because of their Internet connection. They noted this may affect the activity time and make the whole collaborative learning process longer, thus affecting the quality and continuity of collaboration.

As for the issue of using the software, not all students were familiar with the communication tool that was used (Zoom), but, the communication process was an essential aspect of the whole learning experience and the ability to collaborate. Comments in this regard included the following:

> *Some of our team members took a long time to do their duty because they were not familiar with communication tool Zoom software and had poor skills in this aspect; they needed to be trained before the activity, which would have been made improvements to their performance. (S09).*

The related issue of the Internet speed that can either make the process faster or slower, which led to delays in reaching the next step in the collaborative problem solving is evident in the following responses:

> *When teams are having issues with the task, the root of the problem can often be found in poor Internet. (Y01).*
>
> *Internet speed may make poor collaboration and impact team members' effectiveness. (R02).*
>
> *Maybe there was a disadvantage such as in communicating when people get disconnected, they may take a long time to come back if the leader is not skilled to manage the Internet slowing down for some time. (Y08).*
>
> *Internet speed may make poor collaboration and spoil team member effectiveness. (R05).*

Related to this is the participants raising the issue of *time* as an inhibitor, including time management and time zone as noted earlier. This was seen as a critical issue that can prevent collaboration and interaction in RALs. Students stated that being in a different time zone can affect the efforts and energy of students, and in turn the quality of collaboration and time management. This was seen as a potential challenge, although effective time management on the other hand can help to achieve outcomes and save time in the activity. Thus, it was emphasised that it was essential to determine the right time for all team members to engage in the activity:

> *Time zone also affects the collaboration because the time differences reach 10 or 12 hours between different countries; it's essential to select a suitable time for all team members. (R05).*
>
> *Different time zones between countries may affect my effort and energy depending on which time of the day. (Y08).*
>
> *The communication with different time zones may become a problem. (Y08).*

Moreover, the actual management of the learning experiences was noted to have taken more time than expected, particularly when questioning and answering took place. It was pointed out that this could negatively affect learning activity time. Thus, the learning activity opportunity without time management may result in the activity not being completed and the major understanding not being grasped:

> *Sometimes when a member has been asked an expected question and it takes him/her some time to answer, this may affect the activity time and delay the learning opportunity for others. (R02).*
>
> *Time management was one of the challenges. (Y01).*

Languages also emerged as a recurring theme in terms of participants noting that students came from different first language backgrounds, used a different tone, and in some instances English language skills were perceived as weak). Raised by eighty percent of participants, this is a critical issue to consider, as depending on any impact on the ability to communicate it can limit communicative interactions in RALs. Thus, language as a tool of communication is essential. Ineffective communication or weak language causes collaboration to be inhibited, and it decreases the sharing of knowledge and is challenging to effective collaboration.

> *The principal issue is the need for students to have the language to communicate because it's tooled for sharing knowledge. (M07).*

Because of the clarify of the activity when undertaking the task and all its steps, the difficulty was not with the activity itself but the level of communication and the effects of language difficulties when dealing with group members. This was reinforced in the following comments:

> *Maybe the language is one of the challenges I have faced because it's fair to speak words, but weak language mean I have to understand another way that affects negatively on the collaborating that may make you shy. (N06).*

> *. . . they speak a common language like English with different accents, this makes understanding issues and some words hard as the leader covers those shortest by clarifying the unclear word for the team and organising the questions and answers between the team members. (Y08).*

Consequently, differences in accent, when conversing or discussing concepts was the principal element of concern regarding communication between team members. It was not always easy to understand the accent when pondering different ideas or other meanings. This can make collaboration more complicated and can have a negative impact on collaboration as members of the group may get the wrong idea about the concept of the activity. Rather, it may impact on the correct exchange of information relating to the whole activity.

> *Some people have different accents, other people are not used to; as a result, you cannot understand what the meaning or ideas s/he meant. (N06).*

> *The languages as well, if they were different on accents or communications dialects, I prefer the associated device (interpreter) to resolve this issue. (O010).*

> *Overall English language is common in the world, but the differences in accent may make the collaborating more difficult because the team members needs to understand what others said about the task. (R05).*

Familiarity with the topic referred to the possibility that participants may have no previous background or different specialty information regarding the topic. If a student is not familiar with the topic, it can be harmful to the process; it can be a waste of the time and make the students feel under pressure and result in poor collaboration. While participants were from the Faculty of Engineering they represented electrical, electronic, mechanical, mechatronics, civil and construction, therefore, some of the participants faced difficulties because they do not have a lot of prior information on the subject so it took a long time for them to understand the overall concept. Thus, related to this eighty per cent of the respondents stated that unfamiliarity with the topic was one of the significant factors that could inhibited collaboration in RALs:

> *Some team members have no idea about the basics of electrical circuits, so they need more time to understand the concept then to participate in the tasks which weakens the collaboration. (Y01).*
>
> *The collaboration was reduced when the team members did not have a good background in the area of the topic and other communication skills. (O010).*
>
> *If a member is not familiar with the theoretical background s/he needs more time to be on track with others, their background was essential because it can be useful to support each member and also identify any models or figures or photographs without requesting more clarification so working on the task without any issues, and they did not need explanations about theoretical knowledge, however, if members are not familiar with the theoretical background they need more time to be on track with others. (Y08).*

In regard to *leadership*, sixty per cent of the respondents stated that choice of a leader was one of the significant factors that could inhibit collaboration in RALs if not carefully carried out. This was because if a leader fails in their duty or makes the task too challenging to accomplish the activity through teamwork and collaboration the experience would be unsuccessful. Thus, the students appreciated that it was essential to have a leader with the best qualities e.g. the requisite expertise in being able to organise the session and manage the task and learning activities and foster the collaborative dialogue.

> *The leader was the most vital person because he can struggle for the teamwork; if the leader fails the team will fail. (O010).*
>
> *But if the person or the leader wasn't the right person, or he didn't know the method or the task or he didn't know how to be a leader and how to participate to create a discussion between the students! Yeah, it's going to be an issue also. (R02).*
>
> *If there was a bossy person as the leader who could not control the activity things would fail, because other team members would do the activity as fast as they can, so they will not be focusing on understanding the tasks; also if one member has a question to discuss . . . in short, a poor relationship has a significant effect on being able to work collaboratively. (Y08).*

Finally, the quality of the *relationship* between the leader and the team and between team members was raised as a possible inhibiting factor by forty per cent of the research sample. These participants explained how the relationship could become a barrier in adopting collaboration, primarily through the difficulty of communication and the lack of proper understanding of dealing with other people who do not know each other or have met for the first time. Thus, having positive interpersonal relationships was seen as significant for successful teamwork. Team members who do not know each other before the start of the activity or have only met for the first time without any previous relationship may experience some difficulty in communicating and, therefore, be less able to collaborate.

> *If the team member has not known participants before or is meeting them for the first time, I think there will be some difficulty with communication until you get used to dealing with them more than once. (O010).*

> *If I don't know the team members before the activity, the beginning of the activity may be have low collaboration. In short, the relationship has a significant effect on being able to work collaboratively. (Y08).*

5.3.1.3 Difference

The emergent theme of *difference*, related to students' perceptions that the members of the team brought different perspectives, and opinions to the situation and made different inputs into their discussions. The point was made that there can be variation in everyone's understanding of what they read and conclude, such that this is a significant factor that can influence achieving positive outcomes and enriching their experiences in the collaborative time. However, they also noted that the activity group, although from different backgrounds and cultures, it was valuable to draw from their knowledge and understandings.

Most of the students perceived that the differences helped them achieve successful collaboration, while others felt variations in accents might reduce collaboration. However, the leader's help could assist in overcoming obstacles relating to these different backgrounds, values and experiences, opinions, thinking and understandings, and inputs. Consequently, students mentioned that these diverse backgrounds and experiences led to different views, thinking and knowledge, which they considered essential for their effective learning during the collaborative activity. Moreover, they stated that different backgrounds, different understandings of the same information, and problem solving experimental method increased the collaboration.

Students also perceived that team members’ *different background* helps to understand information and problem solving as a result of disparate views. This view is supported by the following statement from a participant:

> *When there was lab activity the understanding level helped students with low level knowledge to catch up and transfer the knowledge also the understanding of any issues with different background understanding for the same information, and the solving problem method differences that will help team members be involved more than other times. (R05)*

Offering a *different point of view* resulted in supportive relationships and the participants listened to each other with respectful behaviour. As quoted below:

> *In our case, every team member had a good relationship between each other there was no aggression or the discarding of other opinions even when members differed in their point of view, but every member respected the differences and listened to each other’s. (O010).*

Also, *difference in nationality* helped to improve and support collaboration, as stated below:

> *There were different nationalities, but this made the collaboration work better, and some of the team members had good theoretical and practical experiences, which also supported the collaboration and working as a team, on other hand, some team members had little experience and needed some help from other team members, so all work was organised and the job done correctly. (Y08).*

Therefore, *leader assistance* was seen as being able to reduce obstacles and make collaboration smoother, as quoted below:

> *The communication method, especially when there are differences in culture and languages, the leader role was essential, . . . to be in the position to reword some difficult words or sentences. (R05).*
>
> *Also, the leader was essential in this collaborative activity because managing time, questions and answers, and when there was a misunderstanding or different opinion the leader went to another method to solve the differences by*

> *supporting the more correct idea or suggestion . . . to make more understanding and other views more explicit, and maybe the team member accepts the leader's advice or gets another new idea. (R05).*

5.3.2 Interactions

Collaboration involves communicative interactions where the students in this case dialogued synchronously and discussed the Voltmeter Divider Experiment task and learning activities. The leader played a part in guiding and monitoring the process and talk, which may include some clarifying and negotiating if there was a disagreement in the team. This theme encompassed four main sub-themes that related to increasing the interactions of the participants. These sub-themes are listed below and are discussed in the following section:

1. Promoting interactivity.
2. Sharing.
3. Questioning each other and explaining.
4. Confirming challenging knowledge.

5.3.2.1 Promoting interactivity

Discussing with others in promoting interaction between participants can bring new ideas and build knowledge. Discussions can clarify, promote new and unexpected ideas, and teamwork can also improve the quality of interchange and listening skills, which ultimately help the students to understand the procedures and the task. The importance of this as perceived by the students is evidenced in the following comments:

> *I consider it with the team members; this practice has helped me to understand the methods and the job because the topic was new for my knowledge. (M07).*
>
> *The most critical experience will be achieved during teamwork in learning how to discuss and interchange and listen to new ideas that never come to your mind. That's a benefit from collaborating. (O010).*

As part of this subtheme *helping others* to connect past and present learning was also seen as beneficial, and this was made possible because students needed to share and transfer information between each other. It also assisted the team to step forward to gain the information to understand the new concepts. In turn unclear or missing information was able to be clarified by other team members to make it more understandable as noted in the comments below:

> *The advantage of collaborating was sharing and transferring the information between different level members and helping the team to step forward to get the information and understand the concepts. (O010).*
>
> *If I did not know something or part of this task was difficult there was a high possibility that one of my colleagues could help with understanding the job. (R02).*

The students were also conscious of contributing to *teaching others.* This referred to the fact that by accepting another opinion, even though members believed that their views were correct, they were educating each other and gained the correct result at the same time. Also, because they brought different skill levels to the learning activities (background, laboratory experience) this appeared to result in a more stable and stronger collaboration within a team to gain the required knowledge and skills to solve the task. The approach, therefore seemed to teach the participants that helping each other in enhancing their existing knowledge or correcting wrong assumptions was a significant benefit of sharing knowledge in a group.

> *Yes, I can accept their opinion even though I think I'm correct. After taking their views to filter the perfect idea, maybe you think your opinion was right, but perhaps other views are the correct solution. But, when your opinion was correct it may have taken more time and cost to get there. (N06).*
>
> *If each member has the skill and another has the background, and another has laboratory experience, this will make the activity stable and a stronger collaboration with the team. (O010).*
>
> *This task teaches me that this kind of working helps in enhancing the existing knowledge or correcting the wrong thoughts, and that was the benefit of sharing knowledge in a group. (O03).*

Similarly, respondents said that *supporting and assisting others* has a positive impact on collaboration in RALs. Based on their responses, supporting and helping others enhances the capability of collaboration. This is despite unexpected problems that may arise during the activity. By sharing and transfer of knowledge and understanding of a concept, learning is made easier for students with less-experience.

> *With respect to the laboratory experience it distinguished between the members whose had prior expertise, who could help team members during the session. (O010).*

> *Some members did not have a good background, and some of them could not contribute without support from other members. In, in this case, the leader had to discuss with them on an easy way to support, and the coming back to the task issues, this was an advantage of collaboration to assistance. (O010).*

The participants also identified the importance of *challenging their knowledge* in the approach being able to facilitate their collaboration. Also, they recognised that every team member needed to contribute their knowledge to others, and how dialogue and discussion should be shared. All team members faced some challenges to enhance their learning; however, it allowed them to test the credibility of their knowledge as well.

> *On this activity every team member needs to contribute their knowledge to the activity understanding, the most important parts of the activity is the dialogue and discussion, which should be shared, and all team members have some challenges to help solve the problems. (O010).*

Finally, the participants perceived that *trusting others* helped guide them to an accurate answer. Confidence and trust meant them creating a bridge between each other, which supported the exchange of ideas. The developing of a good relationship also helped to overcome obstacles and enabled positive interactions to be achieved.

> *The response was expected from them without ignoring my inquiry . . . . Besides, I trust them to guide me to the accurate solution. (M07).*

> *Trust yourself enough to trust others. Innovation requires breaking down the old rules of thought and creating new ones. This means each member of the team must become more transparent than ever before. (Y01).*

5.3.2.2 Sharing

Students reported the importance of exchanging information and opinions and understanding the activity to facilitate their learning. This exchanging of information/views between group members was essential to successful collaboration. They valued this type of interaction during the activity and presented different perspectives: such as a pleasant attitude and a friendly atmosphere. All participants understood the activity and gained a good knowledge of others due to information sharing. Also, they acquired information quickly and easily from the exchange. Moreover, the data was wholly circulated throughout the group. These views are supported by the following statements:

> *It was a helpful attitude in collaboration with this team well as sharing the ideas and knowledge, and this makes the activity simpler to learn; if there was a hard question it could be discussed to get the information fast and more comfortable from the same sitting. For example, the conference tool, I was not familiar with it, in this circumstance members helped me to solve those issues. I came back on the same page, and then I got the concept. (M07).*

> *Even though the field was not my field, I must understand the activity and I got good knowledge from other team members because we were sharing the information, so I can say I learnt something new where I can share with my colleagues during the task online. I hope we can apply this approach to my university. (R04).*

The information was correctly circulated through the team members, and clarification provided on challenging aspects. There was a friendly atmosphere, and all involved were sharing the same information aimed at reaching agreement on the solution. The collaborative process was noted by student O03 as *increase learning in a relatively short timeframe, which makes completing the next step quicker*.

5.3.2.3 Questioning each other and explaining

Questions were another critical factor that the study found to be essential when considering whether to adopt collaboration in RALs. Seventy per cent of the participants thought that this opportunity was an indispensable factor in the approach. It was seen as needed for thinking about and revising ideas and gaining new ideas. It also helped each team focus their attention on the task requirements and helped improve their thoughts and opinions. Moreover, it demonstrated that increased discussion and collaboration was occurring. This is reinforced by the students' comments.

> *The work was excellent, and the team members were collaborating well, which means we got the new fresh ideas, sometime during the activity discussion and asking questions from all members we get the new novel ideas by answering*

> *those questions we could get a good collaboration and working team talent. The original approach and knowledge helped me to discover more and more. (N06).*
>
> *Some of the team members asked questions for clarification if their thinking was okay; this helped all team members to focus and draw attention to the issues involved and improve their ideas and opinion. (S09).*
>
> *I preferred by the group because there were questions, I cannot understand, or if hard I needed more clarifications from another member who was able to clarify; I will benefit from their experience. (Y08).*

Further, through collaboration their difficulties were dealt with more authentically through discussion, which contributed their understanding about the task. Also, it meant spending more time to explain the theoretical background, thus making the task more comfortable and less time consuming.

> *If it was the first time, I think I spent enough time to explain the procedure to the students. It will make it easier and faster. (R02).*
>
> *Sometimes the question was unclear to some team members because their major was not electrical and they didn't know the basics of the circuit, in this case, they asked another team member to clarify and explain the theoretical background to be able to answer such a question. (Y01).*

5.3.2.4 Confirming challenging knowledge

Confirming and reviewing the participants' data from the experiment was central to the collaborative interactions with regards to the problem solving aspect of the activity in the RALs. Also, discussion and interrogation with each other elicited more opinions, which lead to obtaining a satisfactory result because they had come to grips with different types of thinking, which could enhance their learning and allow them to build new knowledge. As the following students' comments show recent and precise information can be accumulated, along with confidence and the ability to understand the laboratory task:

> *It was vital to share ideas to review the information; it means you need to reduce the non-benefit information from your thoughts when new precise*

> *details will have accumulated in your mind, because sometimes trust in an idea and subsequent discussion and sharing with another member became an inappropriate idea, which is the most essential advantage of collaborative learning. (O010).*
>
> *Sometimes I had the answer, but I could not share it unless I had heard from the group and I went to the group view to solve the issue; sometimes a person feels they are not sure if their answer is correct or not when s/he listens to other members taking one direction to solve the problem but the collaboration and teamwork supports all team members to become successful. (R05).*
>
> *Getting more opinions lead to obtaining a useful finding, because you have taken different types of thinking. (O03).*

5.3.3 Processes

In relation to the collaborative learning, Dillenbourg (1999) discussed processes related to collaboration and how they involve social interactions. The most frequently mentioned sub-themes that emerged regarding 'processes' raised the importance of small group and interpersonal skills, new knowledge and understanding, and thinking processes. These are reported on in the following section.

5.3.3.1 Small-group and interpersonal skills

To succeed in the collaborative learning environment students needs a specific time to reach the goal, as well as having a good relationship with team members. The members need to work as a team in their group in a continuous way and but individually accountable in contributing and making the task easier without wasting time and at the same time demonstrate their personal learning. Table 5.5 was developed by using Matrix Coding Query NVivo software and comparing the student frequency talk about the factors. Small groups and interpersonal skills, as shown in Table 5.5, included seven factors: listen, provide effective leadership, build trust, communicate, everyone speaks, manage conflict and be on time.

Table 5.5

Small Group and Interpersonal Skills

Small group and interpersonal skills	%
Provide effective leadership	70 %
Everyone speaks	70 %
Listen	70 %
Build trust	60 %
Communicate	40 %
Manage conflict	40 %
Be on time	30 %

Seventy per cent of the respondents stated that *providing leadership* was one of the factors that improved the group process and led to enhancing collaboration in RALs. Also, a leader must manage the time and dialogue between participants to facilitate the collaboration and ultimately the team's success by being able to organise the process.

> *The leader must have satisfactory character and theoretical and experimental understanding as well able to lead the activity and solve the issues that may have happened, and manage the dialogue as well. (M07).*
>
> *In our team the leader was guiding and managing the procedure and selected two people for controlling and other people just monitoring the experiment. The activity was organised, and all team members knew their duties. I think there were no problems with the collaboration between team members. (N06).*

The subtheme of *everyone speaks or talks* was another aspect of the group processing that emerged from the data. Seventy per cent of the sample referred to this factor. It related to the recognition that everyone can participate equally by giving students the right to express their opinions such that this increased collaboration in the RALs. A student commented that:

> *The team members were collaborative, and everyone participated and gave a chance to others to express their opinion and talk; no-one took more time than others, and the team members listened. I think all members had equal participation. In addition, for example, even though a person had the idea s/he waited and listened to others, and then gave their opinions at the best moment. (N06).*
>
> *To solve this issue, we have not talked to our peer and told him he is wrong because this will be too unproductive for all team members on the activity so*

> *we discuss indirectly, because if one member is successful, all team members will be a success as well. (R05).*
>
> *Build a good friendship with others based on trust and respect. The procedures will help the collaboration with the specific task at a definite time and when you have rigorous objectives. (Y08)*

Moreover, seventy per cent of the sample stated that *listen* could build *group processing*, leading to effective collaboration. Communication between people derives from understanding a range of ideas and the exchange of ideas and translating them into words. Talking or writing involves sharing your point of view with others. Hence, listening involves an understanding of what can be shared with team members, and all team members can be asked for their input. Listening was also an essential tool for communication. Students can support collaboration by communicating and listening to different perspectives. Listening also meant the researcher offered team members the opportunity to participate and give others time.

> *This kind of task gave me a new approach to explain what I need by listening to different opinions. I was comforted with the task because I obtained the information; I need by discussing some unclear parts (R04).*
>
> *Every one of us was given enough time to express his opinion and share his perspective, and at the same time, the rest of colleagues listen carefully for what was saying. (O03).*
>
> *Sometimes I had the answer, but I could not share it unless I had heard from the group and I went to the group view to solve the issue; sometimes a person feels they are not sure if their answer is correct or not when s/he listens to other members taking one direction to solve the problem but the collaboration and teamwork supports all team members to become successful. (R05).*
>
> *If someone disagrees with another, he listens to his colleague's opinion to the end, and then he gives his opinion without interrupting the others. (Y01).*

Building trust was also raised as an essential factor when considering group processing in adopting collaboration in RALs. Creating a bridge of trust between team members was seen as supporting the facilitation of the exchange of ideas. It was seen as necessary for developing respectful relationships. Sixty per cent of respondents referred to this as being associated with the needs of small group communication and the need for interpersonal skills in enabling collaboration. This viewpoint is illustrated by comments from participants as follows:

> *There is a need to build trust and a strong relationship between co-workers: Relying on other people helps build trust, and teamwork also establishes strong relationships with co-workers. (Y01).*
>
> *I trust them to guide me to the accurate solution. (M07).*
>
> *Trust yourself enough to trust others. Innovation requires breaking down the old rules of thought and creating new ones. This means that each member of the team must become more transparent than ever before. (Y01).*
>
> *Build a good friendship with others based on trust and respect. The procedures will help the collaboration with the specific task at a definite time when you have rigorous objectives. (Y08)*

Forty per cent of the respondents also raised the issue of *ease of communication* as one of the factors that improved the group process and led to enhancing collaboration in RALs. This linked to the identification that a leader should have high level social skills to manage dialogue between participants to improve collaboration and teamwork success.

> *In the beginning, the leader should have a strong background and theoretical experience for the topic and high social skills to make communication flow with the team members, and have the ability to analysis the questions. (O010).*
>
> *By using collaboration through remote access helped us to communicate and solve the challenges and to control and manage the laboratory and take the result from the real laboratory via the Intranet. (N06).*
>
> *With this idea for my project, it helped me a lot and saved effort and cost. First, I was not at the university, but I could communicate with other members at any convenient time in which we were available. (M07).*

Similarly, it was identified by forty percent of the sample that the leader needed to *manage conflict* as one of the group processing factors emerging from the data. This included facilitating individual accountability as part of the guided learning activities. Students' comments related to this include the following:

> *Understand the whole activity and how it works, and the possible hazards that may impact the time management, for example how to deal with technical issues and social issues (arguing, debate, disagreeing, conflicting views). (N06).*
>
> *I can be a leader in the activity on my major because I have understood this activity -theoretically. For all sides, managing the time and group tasks, methods of addressing conflict within a team, help to make the task easier by explaining the difficulties, breaking down the other point views or ideas for other team members during the discussion . . . as a result spreading the idea to all team. (R05).*

Punctuality was also raised as an essential when considering group processes; as a factor in collaboration in RALs the sub-theme *be on time* emerged. Being on time is considered important because the activity is based online and depends on synchronisation of the team members' activity, since it is vital to start together and complete the learning experience together and at the set time. Sixty per cent of respondents referred to this factor. The potential for time to be an issue was associated with the time taken to complete the learning activities through the collaborative approach because that required a sufficiently high level of interpersonal skills of members.

> *It was working as a team. It was good because it was saving time. As I mentioned earlier that if you work by yourself, it may be hard to finish it on time. However, working as a team has facilitated all the difficulties. But loss of communication may lead to longer time, which will affect the experiment because you will not finish on time. (R02).*
>
> *People's accents may affect collaboration, especially understanding the conversation or when discussing in key fragments of communication between the team members; . . . the collaboration became hard, sometimes terrible resulting in losing time; . . . poor communication between the team made online communications challenging. (S09).*

5.3.3.2 New knowledge and understanding

Students noted that the challenge of constructing knowledge through arguments/counter questions helped them to confirm their understanding, discover more, and increase their confidence. They were able to discuss how they built up their knowledge based on the different points of view presented by peers on the same issue. This was seen as an important part of their exchange of ideas.

> *Also, there are students who have a good understanding and with collaboration those students will improve their experience from working as a member of the team; also they will improve their attitudes, understanding knowledge and correcting some ideas and broaden their horizons - not the same as the traditional method. (R05).*
>
> *This task teaches me that this kind of working helps in enhancing the existing knowledge or correcting the wrong thoughts; that was the benefit of sharing knowledge in a group. (O03).*
>
> *The work was excellent, and the team members were collaborating well which means we got the new fresh ideas, sometimes during the activity discussion and asking questions of all members we got the new novel ideas by answering those questions we could get a good collaboration and working team talent. The new ideas and knowledge helped me to discover more and more. (N06).*

In general, the activity was supported by the leader’s leadership and other members and the interpersonal relationships in the teamwork, thus fostering participants’ knowledge and understanding.

5.3.3.3 Thinking processes

The importance of thinking processes emerged as an essential sub-theme under *approach to learning*, which was central to the pedagogical change that the collaborative approach required in its adoption in RALs learning environment. Thinking processes involve solving problems and knowledge transfer and the Voltmeter Divider Experiment learning activities challenged and guided students to implement them. These processes are considered essential to building knowledge and understanding and involved students sharing their thoughts in response to the tasks and either accepting or rejection others’ opinions, besides justifying their own. Thus, all the interviewees associated this factor with enabling collaboration. Pertinent comments are noted below:

> *Yes, I can accept their opinion even though I think I am correct, . . . but maybe other opinions are the correct opinion. (*N06).
>
> *On the collaboration work, if you have good relationships with the team member, the communicating will be advanced because they will understand the thinking method and can deal with it. (O010).*

5.3.4 Outcomes

Dillenbourg (1999) described the theoretical elements of collaboration in terms of the effect or outcomes of collaborative learning. Thus, this is discussed in the following section with regards to the emerging themes of the perceived benefits of collaboration.

5.3.4.1 The benefits of collaboration

Important benefits emerged with regards to the adoption of the collaborative approach in RALs. Table 5.6 shows the breakdown of the benefits of adoption according to the analysis of student responses in interviews. Twelve themes emerged with six being raised by fifty to sixty percent of the interviewees and the remainder from ten to 40 percent. These results are reported in the next subsections.

Table 5.6

The Benefits of Collaboration

Benefit	%
Cost reduction	60%
Time-efficient	60%
Remote access	50%
Supporting and assisting others	50%
Sense of reality (hand on experience)	50%
Opportunity for group working	50%
Effort reduction	40%
Availability	30%
Reduce laboratory infrastructure	30%
Increase Participation	30%
Improve Skills	20%
Reduce the level of risk	10 %

Learning in RALs was seen as reducing the costs of students' travel through the provision of the facilities online; as well as students raised the advantage for reducing infrastructure and resources costs within universities. Comments on this benefit included:

> *Collaboration makes learning more accessible, saves time to reduce the cost and reduces the error percentages for going in the wrong direction. (N06).*
>
> *It was so amazing to gather people from whole the world at the same time to discuss some issues and try to reach the benefits smoothly and quickly and that, by the way, will reduce the cost of travelling and the reduce the time west as well. (O03).*
>
> *Collaboration in online remote accesses . . . will save time, effort and cost for any project and makes the distance closer and the job done correctly by synchronising supervision. (S09).*

Although time was discussed earlier as a possible inhibitor the ability to have *time efficiency* through learning in RALs was also seen as a possible vital advantage. This emerged from the interview responses of sixty per cent of the sample. The following comments reflect this view:

> *. . . the actual activity was useful and will save time and effort. Because everything at the beginning is the hardest time and then it will be more comfortable. (M07).*
>
> *The thing I liked most on this activity was improving the probability for time management and dialogue, and prior preparation because it was issued for the team. Also, when all members know the aim . . . and functional purposes that needed to be achieved during the collaboration, the discussion and dialogue will be so easy and save time and effort and high efficiency, because every member knows what their responsibility and other's responsibilities, and not just predicting what was subsequent. (O010).*

Having *remote access* was also perceived as a benefit with thirty per cent of the sample identifying its advantage. They made it clear that when employing collaboration in RALs, access to the remote laboratory and rural areas can create considerable advantages, learning new skills, reducing travel to a distant university to do laboratory work, and saving the financial cost and time. This aspect was also recognised as the facilitator of learning and able to promote the building of new knowledge as evident in the following comments:

> *I have learned from this activity that I can work from a distance and access the laboratory remotely from anywhere; this was an essential point. Moreover, the collaboration work on playing and controlling the laboratory task was a new point for me. (S09).*
>
> *This idea can be done to facilitate the learning for the students from the remote areas and save time and cost, in the same way with excellent construction of knowledge in sharing the task (M07).*
>
> *In my country students travel to the far university to do laboratory work, which costs them time and effort and money. However, this remote access laboratory can solve those issues . . . and also saving for university infrastructure funding. (Y08).*

With regard to *supporting and assisting others*, forty per cent of respondents said that this would have a positive impact on collaboration in RALs. Based on their responses, supporting and helping others was seen as core to the collaborative activity, despite unexpected problems that may arise during the activity. As noted earlier this was viewed as enabling the sharing and transfer of knowledge and grasp of the concepts involved. This was seen as supporting those students who were less knowledgeable or experienced, thus helping to bridge the gap to be at the level of their ZPD. For example, interviewees noted:

> *Some member did not have a good background, and some of them could not contribute without support from other members. In, in this case, the leader had to discuss . . . an easy way to support them, and then returning to the task issues; collaboration was an advantage to assistance. (O010).*
>
> *If I did not know something or part of this task was missing, there was a high possibility that one of my colleagues could help in understanding it. (R02).*

In addition, half of the interviewees identified the importance of the Lab task having a *sense of reality* about it. This was seen as vital to empowering the learning in a RAL environment. This is evident in participants comments as follows:

> *The video-audio communication gave the activity a sense of reality. A human can be transferring the information throughout their senses if the work is correctly done. (S09).*

> *The communication tool made the collaboration easier because this activity based on the remote laboratory in different places delivered real dialogue and debate. (R05).*
>
> *It felt as real as everything I have done before, I have seen other team members operate the equipment without any delay, and we did not imagine this technology would be so authentic. (Y08).*

In turn, this was important to attaining *group work* as part of the collaborative experience. This was identified as another benefit of adopting collaboration in RALs and was seen as an option for learning in general. Fifty per cent of the sample identified this as an advantage. Their comments are reflected in the following comments:

> *The work was excellent, and the team members were collaborating well, which means we got the new fresh ideas, sometime during the activity discussion and asking questions from all members we get the new novel ideas by answering those questions we could get a good collaboration and working team talent. The original approach and knowledge helped me to discover more and more. (N06).*
>
> *If each member has the skill and another has the background, and another has laboratory experience, this will make the activity stable and a stronger collaboration with the team. (O010).*
>
> Also, *effort reduction* emerged as another benefit reported by forty percent of the participants. They shared that by utilising collaboration in RALs, students were able to use their time more effectively and so in that sense reduce the effort to achieve the learning outcome. They were of the opinion that collaborating with other more experienced team members contributed to this as evidenced in the comment below:
>
> *. . . Also when all members know the aim . . . and functional purposes that needed to be achieved during the collaboration, the discussion and dialogue will be so easy and save time and effort and high efficiency, because every member knows what their responsibility and other's responsibilities, and not just predicting what was subsequent. (O010).*

Availability of the learning system and the materials and opportunity to collaborate in learning was another benefit that emerged from the participants interviews. Forty per cent of the sample acknowledged that this was a positive factor for their collaboration in RALs. They also perceived that availability is crucial to working in collaboration anywhere, anytime as this was meant to be. Furthermore, any such factor may create considerable advantages for students and the university with time and cost savings, especially for students at a distance.

> *The companies or universities can take advantage of this collaboration to make the laboratory more available and cheaper. (S09).*
>
> *Working as a team may not be available in some places or universities. In this case, it is necessary to provide a remote laboratory linked to another available location or university to save time and cost. (R05).*
>
> *Working with this system can be anywhere, anytime and in any field. Increase the team member's skills by more training and improve the activity materials. Putting it as a course for students helps make them understand the challenges that may occur in their future work. (S09).*

This reinforces the benefits to university *infrastructure* costs regarding laboratories but has application to other fields.

> *With this mode, the companies or universities can take advantage of this collaboration to make the laboratory more available and cheaper. (S09).*
>
> *The collaboration in the remote laboratory supported both electronic and electrical majors but can be constructed for any experiment from other areas to increase these advantages. (M07).*

The *flexibility* of access to RALs was another benefit put forward by twenty per cent of the sample, which referred to other extra opportunities that learning in RALs provided as it could take place at a distance**.** This notion is supported by the following student's comment:

> *From the laboratory perspective, there was a possibility to have control of the experiment from remote locations and get the result then analyse it . . . like a laboratory and industrial vision from a distance, there can be monitoring of this activity or laboratory and saving of time, effort and cost. (Y08).*

Furthermore, another benefit of collaboration in RALs adoption was the option of *increased participation* for online students. Thirty per cent of the sample saw this as an advantage. Participants' comments noted the following:

> *When there was lab activity the task activities will help students with low levels to catch up and transfer the knowledge and also the understanding of any issues coming from those with different backgrounds or different understandings of the same information; and this different problem solving method will help team members increase their involvement. (R05).*
>
> *By increasing the participation through the task requirements there was more understanding of the concept, and how to deal with the software itself, the idea became clearer as the team members became more familiar with the activity. (M07).*

The ability of the collaborative approach to learning in RALs was also seen by a fifth of the students as being able to *improve skills.* Skills identified included communication and dialogue, understanding knowledge, working with peers from other language and cultural backgrounds, all of which can help broaden a student's learning and communication capacity. The following student's sample comment reinforces this view.

> *The tasks that need many years to learn can be done with teamwork in a year; it saves time and corrects any information that could be wrong; as well the members in this work could improve their communication skills and dialogue skills in the process and be more comfortable to work with the information. (O010).*

Finally, reducing the level of risk was one of the advantages of collaboration in RALs that emerged from a minority of the participants' interview data (10%). Referring to how collaboration in RALs could result in a reduced level of risk, these participants showed concern for the effective reduction of human danger and injury that would be considered a high-risk if the experiment was conducted in a real laboratory with the physical equipment. This is exemplified I n the following participant's comment:

> *The Voltage Divider experiment on remote laboratory practice can reduce the risk because the student stay away from danger equipment and devices as I have seen this example in other real experiment an energy laboratory; it had*

> *a control room and central laboratories, and how to control the turbine was difficult because the human cannot hear in these laboratories because of the high sound safety purpose, and the control room was the control for everything in these laboratories, but were not as comprehensive as this idea that can control many places and many laboratories.(S09).*

The students also indicated that they enjoyed the collaboration since they found it beneficial and resulted in a feeling of happiness. They were of the opinion that the collaborative activity simplified the task and lessened the difficulty of the task since it led to more discussion with their colleagues. Comments in this regard included:

> *It was a helpful attitude in collaboration with this team in sharing the ideas and knowledge, and this makes the activity simpler to learn; if there was a hard question it could be discussed and so we got the information fast and more comfortable from the same sitting. (M07).*
>
> *Indeed, my feeling while doing the tasks was excellent, (R04).*
>
> *Honestly, I have excellent experience in laboratory work, these skills have added excellent character to fulfil the activity procedures for me, and it was a significant thing to be part of this activity. (S09).*
>
> *Also, by being happy during the task because of happy team members makes an enthusiastic and positive team, and their attitude was infectious. (Y01).*

5.3.5 Evidence of Successful Collaboration

This section reports on the students views in relation to Kagan’s PIES – the four outcomes of successful collaborative learning (Positive Interdependence, Individual Accountability, Equal participation and Simultaneous interaction). Table 5.7 was developed using Matrix Coding Query NVivo software by analysing and comparing the frequency of relevant interview talk that reflected these principles of successful collaboration. These results show that the students viewed that these outcomes were largely met.

Table 5.7

Kagan PIES Four Outcomes of Successful Collaborative Learning

Kagan's PIES	%
Equal participation	90 %
Positive Interdependence	80 %
Individual Accountability	80 %
Simultaneous interaction	70 %

5.3.5.1 Positive interdependence

Eighty per cent of the respondents declared that they felt positive interdependence was one of the factors that enhanced successful collaboration in the RAL. Evidence for this stems from the students' comments such as in the following statements:

> *Since we felt like if all team member succeed, that means I am a success. In addition, if some aims are not achieved in the task, it means that it's broken down for all members, but they made this task doable; it meant the teamwork principle had been achieved. Also, it became feedback to the team members that they enhanced their collaborative skills. (O010).*
>
> *The variety of experience and theoretical skills will build the group with teamwork skills and make the leader duty easier, and each member will contribute with their substantial experience to help others become skilled. (O010).*
>
> *This is the difference with teamwork . . . you control your time about thinking, stopping and going, and if you are in teamwork, you must limit the time for each member and the basis of team member's selection to get benefits from all members and the task. (O010).*

5.3.5.2 Individual accountability

Individual accountability was an important aspect of the collaborative approach since the grading of students assessment can be an issue if there is no way to distinguish successful performance at the individual level. Thus, this is a vital outcome to be considered and eighty per cent of the respondents interview data reflected a concern for this. However, their responses as reported below, suggest that there was individual accountability occurring and this could be associated with increased collaboration in the RALs.

> *The thing I liked most on this activity was improving the probability for time management and dialogue, and prior preparation because it was issued for the team. Also when all members know the aim . . . and functional purposes that needed to be achieved during the collaboration, the discussion and dialogue will be so easy and save time and effort and high efficiency, because every member knows what their responsibility and other's responsibilities, and not just predicting what was subsequent. (O010).*

> *Everyone on a team must do the task, and it was necessary to do this task with regards to whether s/he knew others or not especially on laboratory engineering work. Every team member should organise and manage the time, and the duties based on what was needed to be done by each member on this procedure*. This worked well went through the synchronous activity, and otherwise, people would fail. (S09).

5.3.5.3 Equal participation

Ninety per cent of the students stated that they experienced equal participation in the collaborative activity, which, as Kagan argues, should be a core outcome to be successful. According to the interview data the students were able to freely express their opinion and discuss with their peers under the guidance and monitoring of the talk by the leader. Generally, they were of the opinion that there was equal participation although one student reported that he held back on his opinion in order to listen to that of more knowledgeable members of the group first (as discussed earlier). Students' pertinent comments include the following:

> *The team member was collaborative, and everyone has participated and given a chance to others to express their opinion and talk; also no one took more time than others and the other team member listened. I have seen the all members participating equally and time managed equally. In addition, for example, even though a person had the idea s/he waited and listened to others, and gave the opinion at the best time. (N06).*

> *The time was nearly equal between the members accept when there was a problem with communication, technical issues. (N06).*

> *None of the team members took a longer time than others; . . .they had been quick to respond to others and everything went smooth. At the same time, the members who needed clarification may take more time for explanations from other team members but almost the time was equally. (Y08).*

5.3.5.4 Simultaneous interaction

Seventy per cent of the respondents responses indicated that their interactions in the RAL occurred simultaneously in keeping with Kagan’s fourth outcome. They perceived that their opportunity to interact with their peers enhanced their learning outcomes since this caused them to be engaged with the learning activities at the same time. Comments in this regard included:

> *All team members actively engaged in collaboration even when there was an easy task; after finishing the task we ask the members if there was anything not clear; if there was no problem, we went to the next step. (Y08).*
>
> *We were circulating the full information and making sure all team members had received it, also analysing that information, and we understand about what the purposes meant; this objective was achieved through the leader and team members' contributions. (O010).*
>
> *Also receiving each team member’s point of view and the group leader completing their responsibility was a positive point, and it made the group reach the optimum solution with many points’ views being discussed in excellent time. (R05).*

5.3.6 Constructivist principles of learning experience design for collaborative learning (Doolittle 1995)

As a result of the analysis of the interview transcripts using NVivo, evidence was found to support the participants recognition of evidence of Doolittle’s eleven principles of learning experience design enabling their collaboration and interaction with each other during in the RALs. These results are presented in Table 5.8. This table was developed by using Matrix Coding Query NVivo software and comparing the frequency of reference to these that reflected talk these constructivist principles for collaborative learning. The principles are listed in order of percentage frequency counts of students’ thematic reference. While principle one and six received the highest recognition with all students, half of the students referred to principles four and seven, whereas the remainder were mentioned by 30 to 40 percent except for principle two only being raised by 10 percent. The result for each principle is enlarged upon in the following subsections taken in the sequential order.

Table 5.8

Students Responses to Evidence of Their Learning Supported by Doolittle's Eleven Constructivist Principles of Learning Experience Design

Doolittle principal	%
Teach using whole and authentic activities. Principle 1	100%
Instruction or activities must precede a student's development. Principle 6	100%
Encourage self-talk or egocentric speech. Principle 4	50%
Present tasks that students can perform successfully only with assistance. Principle 7	50%
Construct activities that are designed to stimulate both behavioural changes and cognitive/metacognitive changes. Principle 10	40%
Create classroom exercises that require social interaction with peers, parents, teachers, or professionals. Principle 3	40%
Provide sufficient support to enable the student to perform challenging tasks successfully, and then gradually withdraw support as the student becomes more skilled. Principle 8	40%
Closely monitor student progress in order to avoid assigning tasks that are not within a student's zone of proximal development Principle 11	30%
Provide opportunities for verbal Interactions. Principle 5	30%
Students must be given the opportunity to demonstrate learning independent of others. Principle 9	30%
Create a "need" for what is to be learned. Principle 2	10%

5.3.6.1 Teach using whole and authentic activities

The results of the interview analyses showed that the students perceived their learning activity as authentic and holistic in being able to enhance successful collaboration in the RALs. Table 5.9 identifies the sub-themes that emerged from the participants' interviews in relation to this principle. Over seventy percent of students' responses contributed to the sub-themes of opportunity for group work, opportunity to collaborate, creating a polished valuable product, interpersonal relationships, integrated and applied across different subject areas and leading beyond domain-specific outcomes, sense of reality, whereas thirty to fifty percent contributed to the issues of student perception, allowing for competing solutions and diversity of outcomes, complex task, and reflect on learning. The remaining three sub-themes of seamlessly integrated with assessment, ill-defined and examine the task from different theoretical and practical perspectives related to only ten percent of students in each case. However, the points made were highly relevant to the research. The first pointed out the importance of integrating the assessment into the learning activities. The issue of ill-defined, emerged in response to a figure that was unclear that caused unnecessary conversation, which could have impacted on results depending on different

Table 5.9

Authentic Tasks in Online Learning Environments

Authentic tasks in online learning environments	Participants quotation	**%**
Opportunity for group working	Because we work as a group that makes the difficulty also decreases, the collaboration became effective, and the result was more than when you work alone. (N06).	100%
Opportunity to collaborate	Despite it was the first time for me to deal with those students; I can give it a high or high rank because I found all the students were active positive in terms of sharing their knowledge. I found that all people to share their knowledge. They were so active they collaborated with each other. (R02).	100%
Create a polished product valuable	The idea was useful and beneficent and academy and investigational, it was valuable for university student and the laboratory material; it was valuable for a student learned on laboratory and leader skills. (M07). The activity was excellent and good idea and new as well but not new on some major also its good idea to activate this work and bring it back to surface. (N06). I mean lab control was a new technology for me which I find quite interesting and even though I'm working in engineering, so I have started to think about how to use this method in our department. (R02).	70%
Interpersonal relationship	All the team members were very respectful. They criticize so modestly with fully respectful of each other. (R04).	70%

Integrated and applied across different subject areas and lead beyond domain-specific outcomes	I have been knowledgeable than I can make this application on other laboratories and other topics on my life, (M07). I learn something new where I can share with my colleagues during the task online. I hope if we can apply this approach to my university. (R04).	70%
Sense of reality	The idea came to me about controlling the devices remotely and collaborates with other team members after I have done it? I like the idea very much because I felt as real and everything, I have done I have seen it on other team members on life without any delay, and We did not imagine this technology and how it senses like authenticity. (Y08). We were sitting like beside each other's others. (S09).	70%
Student perception	All the students did their best. They were so active. They follow the tasks, and I can see that it was a good experience for me and them as well. It's perfect. It gives me a new experience as a leader control and user. Therefore, as a leader, you can switch over the leader talk to your mates which indicate that does a good thing even if you are far away. This will be an excellent method for the following reasons: Better understanding, Great for off-campus students, saves time and money, Create teamwork. Easy to understand. (R02). Fosters creativity and learning: Brainstorming ideas as a group avoids old viewpoints that often come out of working solo. Combining unique perspectives from each team member creates more effective solutions. (Y01).	50%
Allow competing solution and diversity of outcome	This task teaches me that this kind of working helps in enhancing the existed knowledge or correcting the wrong thoughts, and that was the benefit of sharing knowledge in a group. On the other hand, getting more opinions leading to obtaining a useful finding because you have taken different types of thinking. (O03).	40%
Complex Task	It was challenging to perform it, by using collaboration on remote access help us to communicate and solve the challenges and to control and manage a laboratory and take the result from the real laboratory from the intranet. (N06).	30%

	Based on my personal experience, the task will be hard to understand if I was by myself but working together, and I can say it made it so easy for me to understand the task (R02).	
Reflect on learning	We were doing circulation for full information and make sure all team members have received this information also analysis that information, and we understand about what the purposes mean, this objective was achieved through the leader and team members' contributions (O010).	30%
Seamlessly integrated with assessment	For both on- and off-campus university students, the most significant factor was the proper leader selection, and standard for the student’s assessments before doing the task, because there were students who had high, medium and low knowledge background level to accommodate in the communication to make a balance between sharing the information.	10%
Ill-defined	Something on figures blurred it made more conversations and discussions and more participants for the answer those ill-defined questions, and when they reached to reliable interpretations for all team members.	10%
Examine the task from different theoretical and practical perspectives	I have got different perspectives from each team member to get the perfect answer. (R04).	10%

interpretations. Thus, this emphasised the importance of having accurate clear materials. The third noted how the students gained deeper insights into the problem through being exposed to the group's multiple perspectives. Together these emergent sub-themes are comprehensive in showing the breadth and depth of the learning activity that simulated the actual lab experience, and how students valued the experience. Its authenticity is reflected in the way that it facilitated students' collaboration and ability to reflect on the task and the sense of reality that they felt.

5.3.6.2 Create a 'need' for what is to be learned

Ten per cent of the students indicated that creating a *'Need' for what is to Be Learned* was one of the principles that enhances successful collaboration in RALs. Reference to Principle two emerged from only ten per cent of the students interviewed. However, the following comment emphasised the importance of this need as part of the RALs' task design:

> *If all members get the benefit from the activity in it being necessary for all team members to learn then it will not just be wasting time; the performance will be high as well. (O010).*

5.3.6.3 Create classroom exercises that require social interaction with peers, parents, teachers, or professional

Forty per cent of the respondents reported they felt the exercise involved social interactions with their peers, thus reflecting this principle. They saw it as necessary to be able to collaborate successfully in RALs, because it meant working together amicably to cooperate on the task. Social interaction came about through the exchange of information and sharing the knowledge. When the team experienced difficulty or missing information it was necessary to communicate and discuss to find a solution or clarify. All this makes collaboration possible. Different levels of experience within the team also fostered social interactions, since group members helped and discussed to clarify.

> *There were high and effective collaboration and interactivity during the learning activity, as well as team members, who had less understanding, took the advantages to ask for help to make the task more understood*. (Y08).

5.3.6.4 Encourage self-talk or egocentric speech

Fifty per cent of the respondents referred to the way they had put this principle into practice in their learning in the RALs' experience. Self-talk or thinking or thinking out aloud can facilitate thinking and the metacognitive processes in working on a problem-solving task. In this research the design of the learning activities allowed for the fostering of self-talk through the structuring of the experiment and making learning visible. The following student comments support this principle:

> *We can put any value of resistance and we can see what happens for the voltage and everyone can see that from his computer at the same time. (R04).*

> *So, I think this is the second step which is similar - just to show how to control so that I show you what we did before. (Y08).*

> *So, if you change the value of the resistors you can change the voltage and, in each resistor, and I think in the second case the maximum and minimum, so you just can focus on the voltage in one resistor. (O010).*

5.3.6.5 Provide opportunities for verbal interactions

Thirty per cent of the students mention that the assigning of different tasks and roles in the activity and the experimental joint problem solving caused them to collaborate with their peers. This was seen as enhancing the success of the collaboration in RALs as the following comment infers:

> *Also, if there were unclear points, there was real-life and voice communication conference tools available so you could ask any member or discuss after a member had finished his response* (Y08).

5.3.6.6 Instruction or activities must precede a students' development

All participants agree that the activity or instructor must lead the students' development. This is seen as crucial to facilitating learning because the experiences presented may make it very difficult for students to achieve the target or hinder learning if this sequencing is out. As well, the fostering of knowledge and understanding, engaging in self-talk or thinking out loud were also considered to be a valuable aspect of this activity. The following student comments reflect this principle.

> *The work was outstanding, and the team members were collaborating well which means we got the new fresh ideas, sometime during the activity discussion and asking questions from all members we got new novel ideas by answering those questions, we could get a good collaboration and working team talent. Working as a team, the new idea and knowledge helped me to discover more and more. (N06).*
>
> *The team members were collaborative, and everyone participated and were given a chance to express their opinions and talk; also no one took more time than others and the other team members listened. . . . In addition, for example, even though a person had the idea s/he waited and listened to others, and gave the opinion at the best time. (N06).*

5.3.6.7 Present tasks that students can perform successfully only with the assistance

Fifty per cent of the students responses raised this issue. In addition, the whole RALs learning activity design held a certain amount of challenge for the students to complete such that they needed to discuss with their peers. For instance, the following student explains how his experience required him to work with colleagues to achieve a solution:

> *In regard to the activity it was to control in the remote access laboratory system; this was a definite concept and excellent to solve many issues that could not be done in the same time and different location; it was challenging to perform it. By using collaboration through remote access helped us to communicate and solve the challenges and to control and manage the laboratory and take the result from the real laboratory via the Intranet. (N06).*

5.3.6.8 Provide sufficient support to enable the student to perform challenging tasks successfully, and then gradually withdraw support as the student becomes more skilled

Forty per cent of the students interview responses showed their recognition that providing sufficient support to enable performance and then reducing it gradually was a successful strategy in their learning in the RALs. The following comment supports this belief:

> *Also, if the task starts from easy to hard, the collaboration will increase commensurately. If the hardness of the task increases the collaboration increases*. (Y08)

5.3.6.9 Students must be given the opportunity to demonstrate learning independent of others

Thirty per cent of the students mention that responsible for performing the task individually was one of the principles that enhanced successful collaboration in RALs. This also links to Kagan's individual accountability outcome.

> *The activity was laboratory-controlled, with some experimental or devices online or remotely, by working as a team to get the outcome and write a report after analysing the data achieved from the activity, with the possibility of switches to control the tasks through the members but give each member control and doing their duties by themselves, because there was one member in control each time for this responsibility*. (Y08).

5.3.6.10 Construct activities that are designed to stimulate both behavioural changes and cognitive/metacognitive changes

Forty per cent of the respondents expressed views that supported this principle. There was strong support for the way the learning activities in RALs were constructed and designed to stimulate behavioural change and cognitive/metacognitive change. This was because they recognised that the leader's role contributed to stimulating the group's interactions and dialogue in the context of needing to solve a problem together, This in turn was seen as causing students to not only think to speak themselves but think about the task in relation to what others said in order to comment meaningfully in the group's search for a solution. The leader's instruction and guidance had the ability to control the behaviour during the activity and deal with any expected difficulties that may occur, including technical issues or social issues. It was also important in the view of participants that the leader was organising and guiding procedures and that team members were aware of their duties, and could organise their time and responsibilities accordingly. Lastly, the ability to plan made the activity more active and saved time. Comments in this regard include:

> *This task teaches me that this kind of working helps in enhancing my existing knowledge or correcting the wrong thoughts and that is the benefit of sharing the knowledge in a group. (O03)*
>
> *I am able to put any value of resistance and we see what happen for the voltage and everyone can see that from his computer at the same time, it is a good refresh for my information about electrical circuits. (Y08)*
>
> *Collaboration with the team was easy and helped me to be involved in the activity as I had doubt and struggle to understand this activity for myself. I discussed it with the team members. This practice has helped me to understand the procedures and the task because the topic was new with respect to my knowledge. (M07)*
>
> *Working as a team the new idea and knowledge helped me to discover more and more. (N06)*
>
> *This task teaches me that this kind of working together helps in enhancing the existing knowledge or correcting the wrong thoughts and that is the benefit of sharing the knowledge in a group. On the other hand, getting more opinions lead to obtaining a good finding because you have taken different types of thinking. (O03)*

5.3.6.11 Closely monitor student progress in order to avoid assigning tasks that are not within a student's ZPD

Thirty per cent of the students' responses related to the issue of monitoring student progress with regards to their learning experience in RALs. It was clear that these students showed an appreciation of how the structuring of the collaborative process that was guided through the design of the task and learning activities worked to facilitate the monitoring of students' progress regarding their ZDP. However, this also revealed that it is necessary to consider students' language and cultural backgrounds that may intervene in their ability to learn. Yet, the fact that there was collaboration and cooperation students seemed to be adequately supported during the learning episode in RALs. This is reflected in the following students' comments.

> *Collaboration with the team was easy and helped me to be involved in the activity as I had doubt and struggle to understand this activity for myself. I discussed it with the team members. This practice has helped me to understand the procedures and the task because the topic was new with respect to my knowledge. (M07).*
>
> *In our case simply succeeding was the purpose of this work, to get the right information and discuss the different perspectives to gain a better level of understanding of the task. For example, some members struggled with every piece of information because they lacked some knowledge or had communication-based problems. These were solved through the help from other members in introducing, repeating and arguing for the right answer. (O03).*

5.3.7 Learning experience

With regards to students' views of the learning experience in RALs two sub-themes emerged in terms of their perspectives on the activity and their positive attitude to the experience. Table 5.10 shows that almost three-quarters of students' responses lead to the emergence of their perspective and sixty percent referring in some way to their positive attitude. These students also revealed that this learning experience was something they would like to make use of in the future. This is an important result since the students would have been largely most familiar with a more traditional approach to learning and one that did not involve learning online in this way. Thus, this provides insights into their views about learning collaboratively as well as through RALs and is supported by the comments below.

Table 5.10.

Learning Experience

Learning experience	%
Activity perspective	70%
Positive attitude	60%

> *I have gained knowledge so that I can use this application in other laboratory situations and on other topics in my life, also working as a team to solve the issues I have faced at the start of this activity was very informative, and the remote laboratory situation was good for electronic and electrical majors and can be constructed for any experiment from other areas, so students could get the same advantages. (M07).*
>
> *The activity was excellent and a good idea and although new for me as well, it was not new for some majors but was still a good idea to activate this work and bring it back to surface. (N06).*
>
> *This experience drove me to be interested in this work, and I loved getting more information to learn more and more; also doing this activity has given me an advantage to be able to do this with my projects and future work in different fields linking people, laboratories, universities and research centres to get these benefits. The task was easy going and the sequence and timing was managed in an excellent manner. (S09).*

5.3.8 Need to improve

With regards to the theme in needing to improve this was supported by the sub-themes of *increasing participation* and *improving learning*. Table 5.11 reports the results of the percentage of frequency counts in relation to these two sub-themes. The collaborative process and the stepped sequence of learning activities highlighted the challenge presented by the Voltmeter Divider Experiment that involved problem solving and the manipulation of variables. Thus, it seems that the concept of 'learning' was well established as was their awareness of the research implementation of the collaborative approach as was the RALs initiative. Students comments are reported below.

Table 5.11

Need to Improve

Need to improve	%
Increasing the participation	70%
Improve learning	50%

Students commented with regards to increasing participation in the learning experience as follows:

> *Participation could be increased by increasing students' understanding of the concept, and how to deal with the software itself; the idea was clear when the team members were familiar with it. Authentic learning, for example, like the electric fans experiment, was useful as an example to make the activity more understandable, because of its relevance to life and sense of reality. (M07).*
>
> *. . . the advantage of collaborative learning involves getting information from other experienced members of the group and their knowledge; you will discover that you need these new ideas, and then the old information will be corrected; also this work will make you self-confident and open up the field to make more discovery. (O010).*

Students commented with regards to improving learning as follows:

> *. . . getting more opinions leads to obtaining a useful finding because you have been involved in different types of thinking. (O03).*
>
> *All the team members get the specific objective from the collaboration in a different way, such as enhancing their knowledge or making a good relationship with other team members. (O03).*
>
> *This idea can be done to facilitate the learning and save time and cost and close the distance, in the same way with excellent construction of knowledge on sharing dialogue. (M07).*

5.3.9 Collaboration acceptance

With regards to the theme on the acceptance of the collaborative approach to learning two sub-themes of *collaboration accrued* and *collaboration better than learning alone*. Table 5.12 reports the results of the percentage of frequency counts in relation to these two sub-themes, showing that the students' views were unanimous in their preference for learning collaboratively. Evidence of their views are shown in the comments below.

Table 5.12

Collaboration - Acceptance

Collaboration	%
Collaboration accrued	100%
Collaboration better than learning alone	100%

In terms of the students' views that collaboration was acceptable and accrued during their learning episodes, they reported having a very positive experiences with their peers through sharing the information. They also emphasised they gained knowledge from other team members. In the case of members who had less informed starting points, they had the added advantage of asking questions to make the task more understandable. Feedback in this regard is reflected in the following participant comments:

> *Even though the field was not my field, I must understand the activity and I got good knowledge from other team members because we were sharing the information, so I can say I learnt something new where I can share with my colleagues during the task online. I hope we can apply this approach to my university. (R04).*
>
> *Collaboration with the group was very successful and the idea of the research was fantastic. (N06).*
>
> *First, collaboration was successful evidenced by finishing the task in the right way. (O03).*
>
> *There was no stopping on collaboration, it was running but at some time during the activity team members needed to understand the specific task; we focused on this in case some members had few past experiences with the communication tools or with the activity itself. In this situation sometimes we gave more explanations; also we collaborated as a team to meet their need by asking questions and giving the answers (discussion between team members), but it took more time than I expected for the total activity. (S09).*

With respect to the students' responses that implied they preferred to learn collaboratively compared with learning alone, all referred to this paradigm shift in a positive way. Moreover, they saw the opportunity to collaborate as saving time and effort, and also introducing different points view, broadening critical thinking and problem-solving. They also felt that the leader role was effective in leading the task and in assisting them to achieve results in a shorter timeframe than if working alone. Collaborative learning was seen as strengthening their learning, producing quality results and alleviating stress as a result of access to information. The following comments support these views:

> *Working through collaborative learning made things stronger, and quality results at the end of the session compared to when this is done individually. (M07).*
>
> *Working as a group was more effective than working alone. (N06).*
>
> *The positive side of the collaborative activity is the worry will reduce on each member, it means that the information will be shared, and each team member will contribute to this knowledge so there will be less struggle to compile the information or to complete the task. Furthermore, every team member will have individual accountability, also any fault will be on all team members and the good for all team members. (O010).*
>
> *In my view working collaboratively was better than working alone. For example, if you want to solve the problem individually - well you are looking at the problem from one side or one angle, but if you work as a team it will include different points view, and the team member will help you to broaden your opinion and to think maybe there is another method to solve this problem. (R05).*

5.3.10 Leader roles

5.3.10.1 Leader characteristics

The students stated the leader should be patient and easy-going, be able to deal with team members; and possess good time management and communication and social skills for dealing with people from different backgrounds and cultures. They also perceived that the leader should have a respectful manner, along with a strong theoretical background and experience in the topic, besides the ability to analyse the questions and progress proceedings by circulating the relevant information. Moreover, the leader’s role was seen as having the responsibility to control the collaborative process, which involved multitasking. The following section shows the breakdown of the perceived leader characteristics for collaboration in RALs according to the interview analysis of student responses. These included: managing time and dialogue, reducing the languages gap, clarifying unclear concepts, correcting the conversational direction, guiding and manage the procedure, circulating the data, breaking the silence and supporting team members. This shows the complexity of the leadership task and the range of skills required in addition to the discipline knowledge and the technology skills as evident in the selected student comments for each aspect.

> *The leader was excellent in circulating the information to all members and getting their comments and their final points of view. In the beginning, the leader should have a strong background and theoretical experience for the topic and high social skills to ease communication with and between the team members, also ability to analysis the questions and manage time and dialogue to make collaboration work well. (O010).*
>
> *In the activity we have done the leader should have the theoretical and experimental experience, and time management was essential for the leader, and dialogue management because sometimes there was confusion about points of view or ideas. The leader should speak and clarify the confusion, the leader needs to have the skill of dealing with people from different cultures and backgrounds. Its preferable for the leader to have these characteristics. (R05).*
>
> *The leader should have patience, be easy-going, able to deal with team members, time management, and should be respectful to other team members. (N06).*

5.3.10.2 Manage time and dialogue

This aspect generated the following comments from students regarding the management of time and dialogue.

> *When working individually you might not recognise, you're going in the wrong direction and wasting activity time and doing it repeatedly a waste of time, cost and effort. That could be saved with working collaboratively. The leader was essential to lead the activity until the end. The leader can return the team to the correct direction without wasting time and effort. (M07).*

> *The leader must have satisfactory character and has theoretical and experimental understanding as well able to lead the activity and solve the issues that may have happened, have happened, management as well as dialogue management. (M07).*
>
> *It's possible to be a leader because I have the background and have understood the idea from the software, also the LabVIEW experience, it would be easy for me to be a leader. Maybe I would face a problem on dialogue management, as it depends on the team member's personalities. (Y08).*
>
> *The leader was good at controlling the time and dialogue and made the members participates. (Y08).*

5.3.10.3 Reduce the languages gap

The students shared the following comments in relation to reducing the language gap:

> *The lead role was essential especially when there were differences in culture and language background where different accents made the leader need to be in the position to reword some difficult words or sentences. (R05).*
>
> *When the language was different maybe this made the collaboration more difficult because they speak the common language like English with different accents, this makes understanding issues with some words/concepts difficult but the leader covers these by clarifying the unclear word for the team and organising the questions and answers between the team members. (Y08).*

5.3.10.4 Clarify the unclear concepts

One participant shared the following viewpoint in relation to clarifying unclear concepts:

The leader can clarify the unclear concepts or answers. However, in this scenario, the leader had to make a large effort, and take time to make sure members understood each other. (M07).

5.3.10.5 Correct direction

In relation to this aspect of the leader needing to ensure the collaborative activity stayed focused and moved in the correct direction, students commented as follows:

> *The leader was essential to lead the activity until the end. The leader can return the team to the correct direction without wasting time and effort. (M07).*
>
> *Also, the leader was essential in this collaborative activity because managing time, questions and answers, and when there was a misunderstanding or different opinion the leader went to another method to solve the differences by supporting the more correct idea or suggestion . . . to make more understanding and other views more explicit . . . (R05).*

5.3.10.6 Guiding and managing the procedure

The theme of guiding and managing the procedure elicited the following comments from students:

> *In our team the leader was guiding and managing the procedure and selected two people for controlling and other people just monitoring the experiment. The activity was organised, and all team members knew their duties. I think there were no problems with the collaboration between team members. (N06).*
>
> *If the specialist in the topic becomes the leader, the findings and the feedback from the test will be highly successful, in my opinion. (O03).*

5.3.10.7 Circulate the data

The importance of circulating the data is exemplified in the following student comment:

> *The leader's job, the communication about learning, the learning process activities, all need to be coordinated because the communication and process are the main points that make sure the group members have the data they need, also as a leader does not prevent team members having the data s/he supports its smooth circulation so members keep up with the experiment. (O010).*

5.3.10.8 Break the silence

This theme raises the issue of the management of the dialogue in collaborative learning and particularly when there is silence. The following two sample comments highlight the importance of building a leader into the process:

> *It's an essential point that the leader gives the team members the right to freely participate and break the silence by giving them time to express their opinion even though it may be wrong; the leader simplifies the issue and helps the shy member to be active on the activity and collaborate with other members. (R05).*
>
> *Also, if the situation arises where one team member takes a long time, we must interrupt him/her in a polite way like 'I have a good idea' or contributing that good idea like other team members. (R05).*

5.3.10.9 Support team members

On the issue of supporting team members, this subtheme emerged from statements such as the following:

> *Sure, feeling less stressful when I was working in a specific group, there was no stress. Moreover, if there was any point not clear, I asked team members without any shyness; also I asked the leader to clarify unclear points. (Y08).*
>
> *The team leader was pleasant, led the team and made the tasks more manageable, in addition to solving the challenges involved. (S09).*
>
> *The leader helped and managed those members who had lower team skills to go step-by-step, as well the leader selected the best time for them to participate without affecting other team members progress. (Y08).*

5.3.11 Summary

This chapter has provided an analysis of the results of the research data collection and related to the critical drivers of collaboration in the RALs learning environment. Furthermore, it has provided the findings related to three underpinning theories: Kagan's outcomes of collaborative learning: Positive independence, Individual Accountability, Equal Participation, and Simultaneous interaction (PIES), Dillenbourg's theoretical elements of collaboration, and Doolittle's principles of learning experience design in keeping with Vygotsky's Zone of Proximal Development in terms of the Voltmeter Divider Experimental task. The chapter presents the findings based on the analysis of interviews with the participants, and reports their views of the collaborative learning experience in RALs as related to the research focus of Kagan’s PIES, Dillenbourg’s (1999) theoretical elements of collaboration and Doolittle’s (1995) eleven principles. The results of this study show that students acknowledged how their group learning experience provided them with crucial academic and social support needed to learn collaboratively in RALs. It presented detailed samples of participants’ comments that indicate they had worked collaboratively, and that collaborative learning on the remote task had taken place between them, based on both the task and interview data findings.

It was shown that students’ collaborative learning in the RALs context was affected by both enabling and inhibiting factors. Factors that enhanced students’ learning included: leadership, preparation; student level; technology; familiarity of a topic; relationship; student task; culture and background; time; questions; experience; languages; trust; difficulty and undefined information; interesting topic; and fun environment and incentive. On the other hand, students reported negative factors that affected their learning, namely: technology; time; languages; not familiar with the topic; leadership; and relationship. All of these factors are explored in detail and similarly, the benefits of collaboration in RALs was made explicit. This was followed by the reporting on perceptions of the learning experience and how students perceived how collaboration accrued. Results of participants’ views on working collaboratively compared with learning alone are also considered along with their perceptions of the importance of the leadership role were provided in the final section.

Overall, the students valued collaboration in RALs in several aspects of their learning. However, they recognised various positive and negative conditions that influenced their group learning in the online context. Students recognised that supporting the enabling factors and controlling the inhibiting factors could enhance their learning and improve their group learning experience and so result in more engagement in the online laboratory, which would subsequently lead to improved collaboration and learning outcomes.

This chapter sequentially reported the result of the study in relation to the research data collection design. The next chapter focuses on answering the research questions and examining collaborative learning theory and the research findings in relation to the research contribution to knowledge.

Chapter 6 DISCUSSION

6.1 Introduction

The purpose of this study was to explore and transfer existing constructivist practical Doolittle eleven principles of learning experience design from face-to-face mode and apply them to an online environment. Subsequently, the study applied a framework to facilitate collaborative learning in an online environment using a case study research approach. Based on the study's results, an instructional framework was designed specifically for the facilitation of online collaboration and, ultimately, recommendations were made to enable successful collaboration in RALs in an online environment based on the evaluation of existing task design principles (Doolittle, 1995). Thus, in this study, the instructional principles were tested through students' learning about the Voltage Divider Experiment in the RALs context. The research was able to identify enablers and inhibitors of effective collaborative learning and determine how to best support students' collaboration in the RAL learning environment, which was delivered through the design of an online platform. This study identified and addressed gaps in the current knowledge that was identified in the literature review about student perceptions of collaboration in remote access laboratories, particularly about their learning. Mainly, the study addressed the change from traditional in-Lab pedagogy learning alone to the social constructivist approach of collaborative learning; and also, the shift to learning online in a RAL environment.

This chapter is organised into four sections which consider the study's theory bases of the research, bearing in mind the research questions and the results of students' experiences and views. Following this introduction, Section 6.2 explores and discusses the research findings through the application of mind mapping to draw out the breadth and depth of the students' views of their experience in answer to research question RQ1. The synthesis of these findings illuminates how the collaborative pedagogical model is enabled and enhanced through the leader's role, and how small group learning interactions depend on effective interpersonal skills. Section 6.3 examines the evidence for collaboration associated with the application of Kagan's PIES, which substantiates students' positive views in providing evidence that collaboration and collaborative learning occurred. Thus, this also relates to answering the first research question (RQ1 students' acceptance). The fourth section, Section 6.4, discusses the contribution to the knowledge of the study's three underpinning theories and how they relate to each other in enabling a collaborative learning approach in RALs. While Kagan's PIES relate to the evidence for collaboration in learning, this section highlights the application of Dillenbourg's theory, which focuses on the elements of collaboration, along with Doolittle's principles of task and learning experience design. This discussion addresses the research questions RQ2 (actual factors for consideration), RQ2.1 (implications for practice) and RQ3 (benefits) in teasing out the ramifications of a shift to collaborative learning in RALs in contexts such as in this research in higher education. The final section, Section 6.5 provides the chapter summary.

6.2 Mind Mapping and Research Outcomes

The results of the research analysis and synthesis were considered through the process of mind mapping (Buzon, 2015). This strategy assisted the researcher to refine the research outcomes in relation to the students' understanding of learning through collaboration in RALs. The resultant mind map is shown in Figure 6.1.

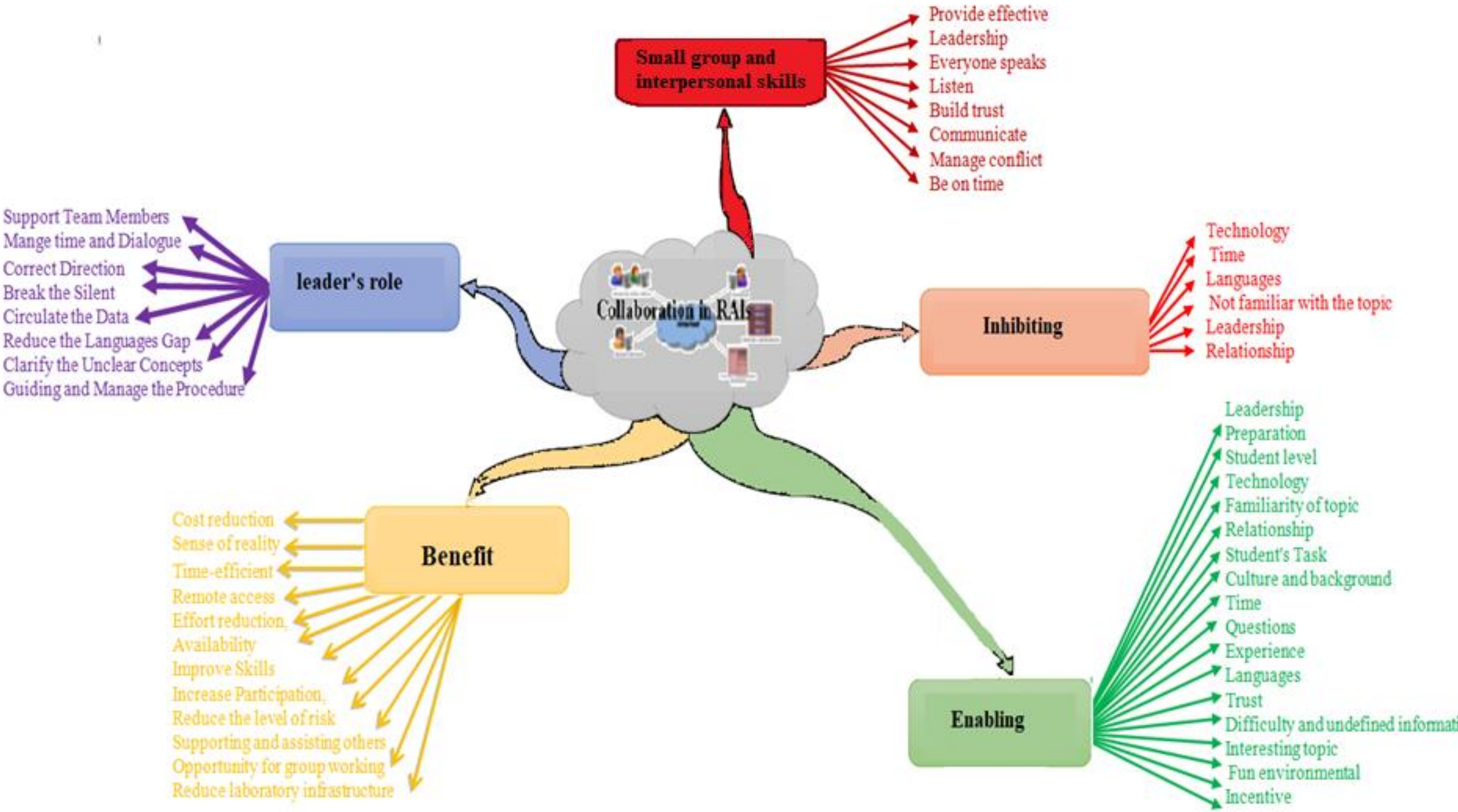


Figure 6.1: Concept maps of students' understanding of collaboration on RALs

The analysis found five major emergent themes, the first of which was *enabling collaboration* as a major underpinning feature necessary for facilitating students' collaboration in RALs. The second significant theme identified *inhibiting factors* that may occur when trying to implement collaboration in RALs, whereas the third theme highlighted the *benefits of collaboration* and the collaborative approach to learning. The importance of the *Leader's role* was the fourth significant theme, which attracted major comment from the research participants. The final and fifth theme drew attention to the vital importance of the *small group and interpersonal skills* that students recognised as essential for collaboration to occur**.**

Figure 6.1 also presents seventeen emergent sub-themes namely, Enabling Collaboration; Leadership; Preparation; Student Level; Technology; Familiarity with the topic; Relationships; Student's Task; Culture and Background; Time; Questions; Experience in Languages; Trust; Difficulty and Undefined Information; Interesting Topic; Fun Environment; and Incentive.

Figure 6.2 portrays the components of the emerging features of the collaborative approach in RALs, reconceptualising these findings in terms of a pedagogical model. It shows the importance of the leader's role and the small group learning context where participants required effective interpersonal skills if collaboration is to be achieved. This is an important finding since other more traditional pedagogical approaches such as standard in-LAB work do not require students to have or learn interpersonal skills, yet they are well-established as necessary in most occupations (Subedi, Lundeberg, & Bunting, 2011). They are vital in enabling effective communication for teamwork, negotiation and problem-solving. While the students were successful in collaborating and identified benefits, this may—to some extent—have been enhanced through their agreement to participate in the research. Nevertheless, clear benefits were identified, as were some inhibiting factors. The inhibiting factors mainly related to the students' dependence on having the technology and time to work collaboratively since the traditional pedagogical approach was monologic rather than dialogic and therefore less time consuming, but limiting as a learning experience, Interestingly the students were able to grasp this contrast between pedagogical approaches given the opportunity to engage in discussion. Students also highlighted the importance of language use being clear as they were from a range of language backgrounds, with English as an additional language. Other inhibiting factors related to the need to ensure the structuring of the task and roles supported the leader to do their part, but also ensured sufficient pre-familiarity with the topic. Just as a small group and interpersonal skills were found to be key to collaborative learning, their limited use of those skills was seen as inhibiting since this meant poor interpersonal relationships within the team. Fig 6.2 highlights the importance of how these features of the emergent pedagogical model relate to each other and emphasise the skills, roles and responsibilities in the RALs dialogic learning context.

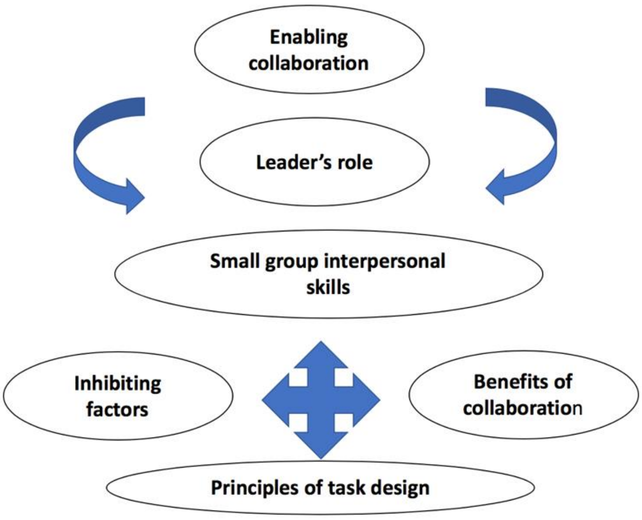


Figure 6.2: Conceptualisation of major themes in terms of a pedagogical model

The benefits of adopting collaboration in RALs highlighted it as an acceptable alternative that increased students' participation in their own learning, and was supportive and cost and time efficient. Moreover, it was seen as readily available and abled accommodation of increases in student numbers with savings in infrastructure while improving skills and reducing risk to workplace health and safety. In addition, the role of the leader was valued in its capacity for the teaching and learning extra skills in time management and management of the pedagogical processes, including in-depth knowledge of the task, providing instructions, corrections and explanations, supporting peers, and facilitating constructive dialogue, all adding value to learning teamwork and interpersonal skills, which are applicable to employability soft skills (Jerome & Antony, 2018). Such advantages were borne out also in the emergent sub-themes underpinning the core element of small group and interpersonal skills that extended to eight branches. They emphasised the skills to not only provide effective leadership but to ensure each team member had a voice, and listened carefully, building trust and being able to manage and conflict.

6.3 Contribution of the Three Theoretical Bases - Kagan, Dillenbourg and Doolittle

This section discusses how the findings from the study contribute to the research underpinning three theories: (1) Kagan’s PIES, (2) Dillenbourg’s elements of collaboration, and (3) Doolittle’s principles of learning experience design, and the implications for the use of collaborative learning as a workable alternative to traditional in-Lab work. Figure 6.3 illustrates how these three underpinning theories relate to supporting an effective collaborative learning environment. They take into account how Kagan’s PIES applied as evidence of collaboration, Dillenbourg's elements of providing insights into the collaborative process and Doolittle’s principles of learning experience design in the discussion of the effectiveness of the task and learning experience design. The figure shows how these three underpinning theories related to each other in the Doolittle principles being central to the design of the learning experience and the next circle represents the broader level of Dillenbourg’s elements of collaboration. Whereas the outer circle shows how Kagan’s PIES represent the outcomes in positioning the learner as having autonomy as a learner and while the learning is collaborative with simultaneous interactions and equal participation there is positive independence and individual accountability.

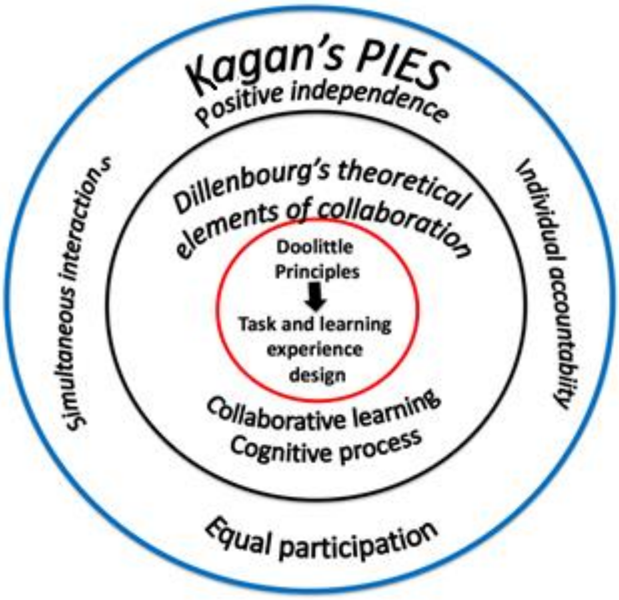


Figure 6.3: Overview of the application of the study's theory base for enabling collaboration and collaborative learning

The first research question (RQ1) for this study was the following: *To what extent is collaborative learning in remote access laboratories accepted by engineering students as a workable alternative to the traditional LAB work?* The extent of collaborative learning, towards Positive independence, Individual Accountability, Equal Participation, and Simultaneous interaction (PIES) was revealed fin the students' expressed experience in the RAL learning environment in keeping with this philosophy. PIES supported the students' path to a fruitful collaboration where they were involved in experimenting together with the Voltage Divider task displaying positive interdependence which resulted in better learning outcomes. This trait from each member of the group is deemed necessary for the group to achieve success. Moreover, their involvement in the designed activities gave them opportunities to develop other positive outcomes such as team members being able to work effectively together and support each other to ensure they completed the task and achieved successful outcomes. Consistent with the findings of this study, Kagan (1992) notes that when PIES are incorporated into cooperative learning and learning preparation, it is more likely other positive effects will ensue.

When positive bonding occurs, students view peer success as being a success for themselves as well, thus promoting collaboration. Individual accountability is also vital because if everyone in the group is not responsible for their learning, much of the group's responsibility can fall on one or two people, which is a common perception of 'group work'. Equal participation was achieved in the present research by giving each student in the group a role that was seen as having an equal value within the group. However, this is not easy to implement unless the roles are changed regularly to allow all students to try specific roles. By ensuring simultaneous interaction, all students were able to actively participate in the task at the same time, such that no individual was excluded during the collaborative learning process (Kagan, 1992). This study found, based on Kagan PIES, that collaboration is accrued, as the students confirmed by indicating that all basic issues formed part of the remote laboratory activity. Collaboration is further illuminated through reference to examples in the discussion of the four elements as follows.

6.3.1 Kagan's PIES - four outcomes of collaborative learning

6.3.1.1 Positive interdependence

Johnson and Johnson (2013) argued that Positive interdependence (Kagan's first principle) is an element that must be present for the implementation of cooperative learning is to be successful. The majority of the students' responses (80%) to questions about their experience reflected that they felt positive interdependence was one of the basics that enhanced successful collaboration in RALs, as was also verified in the video dialogue recordings. The research showed that as students discovered the positive aspects of learning in this way, the success experienced individually was appreciated by students' peers and contributed to the success of the team. Moreover, it was found that all team members felt they needed to contribute to be successful, based on working and supporting their colleagues. Thus, increased positive interdependence was evident in leading to successful online cooperative learning confirming findings by Swan, Shen & Hiltz (2006). Also, the contribution of each member had advantages for their peers regarding substantial experience or skills of other team members which assisted their understanding. Again, the students viewed the collaborative nature of the learning meaning that when the group was successful then that meant each student felt successful as well. The findings from both interviews and observations of the RAL videos of the learning experience showed that students had a positive outlook for working in this situation, reflected by them feeling positive and interdependent, both of which are foundational for enhancing successful collaboration in RALs.

Therefore, the research confirmed that the principle of positive independence is core to successful collaborative learning in RAL activities. In a collaborative learning situation, individuals work together towards the achievement of a shared goal. They work together to increase their individual learning, as well as other team members' learning, and they all strive for the success of the group. Moreover, the collaborative approach was shown to benefit the entire group which they naturally celebrated, in stark contrast to the traditional in-Lab experience that does not value-add to students' learning in that way. This collaborative approach has the potential to engage students in soft skills that are also relevant to their future employability (Hughes, Bradford, & Likens, 2018; Jerome & Antony, 2018), skills to ensure respect between team members, caring for and helping each other with dialogue regarding their learning and problem solving until all team members have succeeded in learning the concept.

6.3.1.2 Individual accountability

The second principle, Individual accountability, is an essential element of any group learning situation. Thus, it is a vital consideration in any collaborative approach to learning. This research also supports the significant factor of accreditation through collaboration in RALs. The students recognised that the performance of each student was evaluated, and the results were distributed to the group. To ensure that each member was respected, students were held responsible, individually, for carrying out their role as part of the shared activity. The majority of students' responses (80%) identified the importance of this factor in the collaborative approach to learning in RALs. Furthermore, they highlighted the importance of the performance of each member of the group being measurable, as well as the need for students to be aware of their individual achievements and respectful of those of their peers as well.

Moreover, the research findings showed that *individual accountability* in collaborative learning activities improves with good time management and a sense of responsibility. Everyone in the team had to be involved in the task at hand, as well as being involved in time management and clarity around individual team member's duties. This finding confirms the prior study of Johnson and Johnson (2013), which emphasised the importance of individual accountability by adding it as one of the five essential elements for successful group work. The present research illuminated such issues, for instance, the potential need for emotional support for students undertaking teamwork, since the change from traditional pedagogy may cause stress. Similarly, working collaboratively may require up-skilling of students to develop their consensus-building skills and, for teachers, the ability to design clear instructions, including those critical for the team leader, and in the online learning space. Such *individual accountability* has been observed, as all team members were required to perform tasks when they had the opportunity and to use a certain amount of time to share and collaborate, Each team was expected to answer the question, the expectation being that each team member participated in finding the right answer, or was willing to receive help from a team member in order to find the right answer or to correct their answer.

6.3.1.3 Equal participation

The third principle relates to ensuring *equal participation*, which in some respects reflects the issue of individual accountability, although the latter implies it is measurable. In the present RALs research into a collaborative learning environment, the majority of the students (90%) perceived that *equal participation* was achieved as it was encouraged through the organisation of the RAL learning activity and the role of the leader, as well as the expectations set for the team members individually. Clearly, without paying attention to this principle, a collaborative learning activity might be chaotic as participants would lack knowledge of their roles and responsibilities. Thus, equal participation was one of the factors that made the collaboration in the RAL successful. Designing the task to this principle also ensured participants were able to express their opinions and talk to each other, which contributed to the activity running smoothly.

Equal participation also relates to the major research theme of the importance of the small group and interpersonal skills in achieving collaboration (Johnson & Johnson, 2013). The students affirmed that each team member took on an active role in completing the given task and that each member was given equal opportunity to gain knowledge from the task and experience interactions with other team members. By structuring equal participation in the collaborative learning experience, students developed enhanced social skills. Students mentioned that they were given a chance by others to express their opinion and talk about the concepts involved and any emergent problems. Thus, the time for learning must be equally shared by students and seen to be fair by them. The team members in this research were quite considerate of each other in their time sharing, as demonstrated in them providing wait-time for their peers' responses, and their willingness to listen and offer ways to assist. For example, participation may be created on an equal basis in a RAL by utilizing a turn allocation or by distributing an equal task. It created an allocation in turn that provides participation expectations for all team members with an opportunity to participate in the activity. and was expected to add to their knowledge or answer questions related to their task and/or role.

6.3.1.4 Simultaneous interaction

With regards to the fourth principle of *simultaneous interaction*, the majority of students (70%) indicated that they felt that they worked amicably with their colleagues such that this principle became one of the core factors that fostered their successful RAL collaboration. They perceived that they learned better when a high percentage of the team was actively working, simultaneously. The recorded sessions were testament to the team members' active involvement from moment to moment in their dialogue. For example, *simultaneous interaction* was observed in the remote laboratories and the number of team members participating can be determined at any given time through the support of the software monitoring system. Similarly, each member can interact and communicate with his or her partner during and after they finish each step of the task requirements while the other team members are actively listening. Alternatively, the collaboration can be structured in other ways to ensure experimentation and manipulation of variables as in the present study and can engage students in questioning and explaining.

Compared with more traditional approaches, with limited opportunity for questioning and critical discussion or with formative assessment (Habibi & Dashwood, 2020) student dialogue in this study focussed on students solving problems collaboratively, using concepts and engaging in feedback to increase their learning. Kagan and Learning (2009) espoused the practice that team members be actively involved in collaborating and circulating all information and receiving the same analysis information. Furthermore, individual accountability, positive group leadership, team support, and clarity of instructions were considered as essential requirements for effective online group collaboration.

Overall, in considering Kagan's PIES in relation to the research findings, it appears that collaboration was accrued successfully such that application of the PIES helped lead the way to a fruitful collaboration in the RAL learning environment. Importantly, the students demonstrated a positive attitude towards cooperating and collaborating in the RAL learning environment, indicating wide acceptance. Thus, these findings applied in the online virtual learning environment and added to the work of Kagan and Learning (2009), besides to the value of the collaborative approach to learning that Villa, Thousand, and Nevin (2010) also illuminated the value of the collaborative approach to learning. For example, simultaneous interaction was observed in the RALs and the number of team members can interact and communicate with his or her partners during and after they finish each step of the task requirements, while the other team members are actively listening. Alternatively, the collaboration can be structured in other ways to ensure experimentation and manipulation of variables as in the present study to engage students in questioning and explaining.

6.3.2 Dillenbourg’s theoretical elements of collaboration

Based on Dillenbourg’s (1999) four theoretical elements of collaborative learning: (1) the learning situation, (2) the quality of interactions, (3) processes and (4) effects, the students’ interview transcripts were analysed for evidence of their presence through the dialogue and discussion. With this theoretical base in mind the discussion in this section responds to research questions 2, 2.1 and 3. Overall, these findings show that the participants gained an understanding of how they could learn in RALs through the collaborative approach. The research also showed the importance of the leader’s role in this approach to learning and the need for participants to have sufficient prior knowledge, the ability to reflect critically, and also interpersonal skills to communicate effectively with peers. Also, the majority of students were strongly supportive of the collaborative approach although it was relatively new to them. The research findings are further discussed in relation to the research questions with respect to each of Dillenbourg’s elements below.

6.3.2.1 Element 1 - The learning situation

The learning situation considers the context for learning, which includes the fact that learning was conducted in RALs. The teaching approach was designed to promote collaborative learning and provide a task relative to the students’ engineering backgrounds. The students were at approximately the same proficiency level regarding their knowledge and learning goals in higher education. The findings in relation to this element identified both factors that enabled collaboration and collaborative learning, as well as some that inhibited them, thus helping to answer the second research question: *What are the actual factors that need to be considered when adopting a collaborative approach to learning in RALs?*

In focusing on the factors to be considered for collaborative learning to be adopted in RALs. The analysis of the interview transcripts via triangulation with data relating to student experiences through the student task report, together with video observations, produced seventeen principal factors that participants identified as *enabling* their collaboration and interaction with each other during the RAL learning experience. These were leadership, preparation, student level, technology, familiarity with the topic, relationships, student's task, culture and background, time, questions, experience, language, trust, difficulty and undefined information, interesting topic, fun, environment, and incentive.

Furthermore, six *inhibiting* factors emerged as needing to be improved, namely, technology, time, and language, unfamiliarity with the topic, leadership, and relationships. Thus, the results of the study highlighted students' ability to understand the changed learning context of collaboration and their roles as learners during their collaboration in the RALs environment. The emergent enabling and inhibiting factors were identified by the students as influencing the quality of their collaborative experience, thus providing valuable feedback on the potential for change from the traditional in-Lab approach to the RAL environment in engineering higher education.

6.3.2.1.1 Significant enablers of collaboration and interaction in remote access laboratories adoption

The research findings relate to the most significant factors that need to be considered for the adoption of collaboration in RALs, as identified by the participants based on their knowledge and experiences. They confirm that *leadership, preparation* and *student level* were seen as the most important considerations when planning to adopt collaborative learning in RALs, with ninety per cent (90%) support. This was followed by *technology* and students’ *familiarity with topic* (80%). Other enablers that received high frequency of 70% highlighted the importance of *relationship, student's task, culture and background, time, questions* and *experience*. While *languages* and *trust* were highlighted by sixty per cent, *difficulty* and *undefined information* were noted by fifty per cent. Other enabling aspects that were identified, but by less than half of the students, were also worthy of consideration as they related to the importance of the task being of relevance to students as follows: *interesting topic*, 40%; followed by *fun environment*, 30%, and *incentive*, 20%.

Having leadership capability was identified as one of the most significant factors that required consideration for enabling collaboration and interaction. The students agreed that leadership was a fundamental aspect of enabling collaboration during the remote learning activity. They recognised that a key factor affecting their experience was the role of the leader in providing direction, and having the appropriate knowledge upon which to draw to give guidance on the task. Students also perceived that they needed a leader to direct the group in terms of managing students' behaviours in that some students may dominate, while others are quiet. In addition, the leader was seen as vital in managing the time and circulating the information to enable everyone to participate sufficiently to experiment and grasp the learning at hand. However, the students were unsure whether they were ready for this independence in their learning or not, which is not surprising as this was the first time, they had experienced both the collaborative approach to learning and learning in this way in a RAL. Nevertheless, they were quite discerning in their assessment as they highlighted how the leader required both social and management skills, and as noted earlier, the research illuminated how effective interpersonal and communication skills were necessary for both participants and the leader. Compared with the traditional in-Lab learning experience, where the demand for dialogue, problem solving and interpersonal skills would be limited compared with the RAL learning experience, it would seem collaborative learning in RALs has much greater potential for preparing students for work.

In addition, selecting a capable team leader can help teams develop more manageable directions and unique patterns of workflow, which may save time and diminish different cultural perceptions among team members. It would also be important to allow students to take turns in taking on the role of leader over time although this was outside the scope of the present research. The need for the leader to be supportive during the learning experience confirms previous research, for instance, offering prompt responses to students' questions when students encounter problems in an online course as this significantly influences learners' satisfaction and benefits (Gray

& DiLoreto, 2016; Jaggars & Xu, 2016). Moreover, the effects of learning activities and students' satisfaction are influenced by leaders' attitudes in supervising learning activities in online courses. These results also align with the findings of Lee, Srinivasan, Trail, Lewis and Lopez (2011) and Xie, Di Tosto, Lu and Cho (2018), which established that students' perceived leader support was significantly related to their overall satisfaction. Thus, it can be said that a shift to learning in RALs means a shift away from a traditional student in a traditional laboratory working in a largely monologic situation to an online dialogic, interactive, collaborative one, where there is more a sense of learning together.

Considering the aspect of preparedness, the need for the team to be well prepared was also identified with high frequency as being essential for enabling collaboration in RALs. The majority (90%) of the students raised this issue. They saw preparation applicable at all stages, including trial, training, and setting up of resource material, as necessary to facilitate the experimentation and learning with the Voltage Divider. The difficulty that the team identified was the need for training more than once before the learning experience to reduce the gaps in knowledge between the different team members. They saw this as being able to make improvements to their performance and help students to participate more effectively. This supports a previous study by Koo (2008) which demonstrated that many institutions have been unable to implement online collaboration because the majority of students are new to this as an approach to learning and are not willing to engage collaboratively in such a new environment.

In addition, the emergent theme of student-level also related to the set-up of the learning situation, as the students made the point that all participants needed to have the requisite level of skills and knowledge necessary to enable them to collaborate and interact with the content and their peers. The majority (90%) of students raised this issue as essential for their active collaboration in the RAL activity. They also pointed out that there needed to be consistency for all members regarding their involvement with the experimental task and problem-solving. They viewed it as vital that all students were equipped with an appropriate level of knowledge, the interpersonal skills to collaborate and deal with others, a sufficient level of commitment to see the task through, and commitment to the quality of teamwork, group learning, and individual contributions. While these findings are in keeping with the results of Bunderson and Reagans (2011) they provide deeper insights into the nature of the communicative interactions and identify the need for interpersonal skills and teamwork. The present research also highlights the importance of ‘student-level’ in that without the optimum preparedness of all group members, group learning may be suppressed. In addition, while quiet students’ skills may be underestimated, at the same time more outgoing or more confident peers may have more opportunities to contribute; and without effective leadership, they may tend to ignore the efforts of their quieter or less-prepared peers. Similarly, the reliance on technology may also be an influence.

Technology and computing services and the innovative approach in the presentation of the Voltage Divider Experiment online demonstrated a reliance upon technology-based communication in this trial of RALs. This was clearly evident to all since the experience depended on using Zoom CLOUD technology, LabVIEW software, the Internet, and the simulation machine. Moreover, these technologies were all vital aspects of the learning experience and their use required participants to have prior knowledge and skills. This recognition by the students is evidenced by the fact that eighty per cent (80%) of the sample raised this factor as central to enabling collaboration in RALs. But they were also of the opinion that the software made the collaboration more comfortable in that it guided and structured their learning as a group. Additionally, the availability of video/voice communication conference tools and the technology facilitate circulating the information among the participants, which was seen as making the process much clearer and faster. While these findings confirm the results of Anderson, Garrison, Archer and Rourke (2003); Gibbings (2014); and Salaheddin Odeh and Ketaneh (2013), the present research highlights the way the design of the learning experience and the attention to the leader’s role and the dialogic nature of the interactions are core to enabling collaboration and collaborative learning. Importantly, being able to work collaboratively is a fundamental feature of how contemporary organizations operate and their work is increasingly being supported by technology. The present research findings add support to the argument that the introduction of RALs and collaborative learning into engineering courses can enhance students’ learning and add value to their employability. Web-based communication systems, such as those used in this research, are increasingly being adopted and widely advocated as tools for collaboration that can support self-explanation, social negotiation, and shared knowledge construction among participants.

The use of technology, and a virtual situation, as opposed to the in-LAB reality was one of the issues that arose regarding the learning situation. Balamuralithara and Woods (2012) noted that the environment, including the technology and the mode of communication within which collaboration takes place, requires students to have a sense of realism, if effective teaching and learning is to take place. However, in the present research, the participants reported that the activity was real to them despite it being achieved through the use of technology online. They were of the view that its originality made it feel like a traditional laboratory, and that the use of video and voice, and the communicative purpose provide a sense of reality. Moreover, the students argued they perceived it as an authentic learning experience. Thus, ensuring a sense of realism in the implementation of the virtual laboratory was found to be essential. In keeping with Altalbe (2018), the use of multimedia and videos, combined with proactivity with regards to technical support, was also found to be central to the success of a virtual laboratory. While Preece and Maloney-Krichmar (2003) believed that the combinations of technologies and the web site access provided a more productive basis for collaborative courses, the present research found that technology choices must also ensure that all students are able to use these technologies and that software should be straightforward/intuitive and easy to use. On this basis, it is argued the sense of reality associated with the present learning experience was reasonably high as the camera and audio used resulted in realistic data and students gaining a feeling of reality (see Balamuralithara and Woods, 2009; Elawady and Tolba, 2009). Nevertheless, Gibbings (2014) points out that even though there is a sense of reality in a remote laboratory this does not necessarily mean students will experience learning in an in-depth way. He argues that deep learning can depend on various factors such as the quality of the guidance activity, and the design of the learning experience and ensuring experiments are in contexts that link to authentic professional work. It can be argued the present research RAL learning experience was able to address these features and the activities also encouraged students to critically reflect on their study. Gibbings (2014) also emphasizes that the RAL task is authenticated by having close relevance to a student’s last industry-relevant experience, thus supporting the use of the Voltage Divider Experiment here. Therefore, this is of vital importance in any planning of the activities/tasks for RALs.

Another technological feature of the research that impacts upon the learning situation was the dependence on a conference tool—in this case, ZOOM software. The conference tool was the principal, critical factor for enabling collaboration. The participants used both video and audio and were required to speak and compose text as a communication tool, taking turns appropriately, besides display/share their screen. Previous research also indicates many positive effects of technology on collaboration. Maintaining a positive collaborative learning experience depended on the effectiveness of the ZOOM system; thus, in this research attention was paid to ensuring students had the necessary skills, and the leader’s role was also an additional supportive strategy. Thus, students’ familiarity with computers played a crucial role in enabling their collaborative work and made a positive contribution to their educational experiences (Song, Singleton, Hill, & Koh, 2004). These findings build on the work of Cooper (2010), who emphasized the importance of conference software such as Zoom allowing synchronous chat and messaging functions, as this also can promote student teamwork.

Thus, the collaborative approach encouraged experimentation, and allowed the sharing of ideas, and facilitated a distributed participation, where there was evidence of collaboration and collaborative thinking and learning. With regards to the Internet, reasonably high speed is necessary. Bandwidth is also an essential enabler for the operation of successful RALs. Most of the students confirmed that Internet speed influenced their participation and completion of their work as their participation depended on their personal arrangements. Thus, learning in RALs, as with any online learning approach, requires students to have personal up-to-date computing equipment and efficient Internet access. Thus, Internet access has been identified as one of the essential factors that need to be considered to enable collaboration in RALs. Some students in this study required technical support to effectively prepare and establish the Zoom online environment, thus showing those contemplating adopting RALs in their teaching need to have adequate technological support on hand (Koo, 2008). Nevertheless, online collaboration and e-learning or using the Internet for educational purposes helps overcome the physical obstacles of collaborative learning and can also be encouraging for some students, who may be reluctant to participate collaboratively in face-to-face learning situations. Thus, when collaborative learning situations and activities are well designed, they can stimulate learning by experimentation and discovery, and at the same time, they can develop reasoning and logic (Garfield, 2013).

The research also highlighted the advantages of RALs as opposed to traditional in-LAB learning in terms of its potential for 24/7 accessibility and potential to foster students' leadership and independent learning, since the high risk associated with operating the actual equipment is mitigated through the simulation software. Moreover, it is incumbent upon educational institutions to implement the technical infrastructure of reliable technical and adequate support, as well as the establishment of access to computers and electronic networks that are adequate to support a collaborative learning environment.

A range of other factors were identified by the students as key to enabling collaboration and maximizing learning in RALs. These related to familiarity with the topic, the relationship between students, task design, students' culture and background, language and accent, time management, opportunity to ask questions, prior experience, trust, the topic of interest, fun environment and incentive. The participants stressed the importance of having prior knowledge of the topic for learning in terms of content within their field. Being comfortable about the topic to be offered in the RAL was important for their confidence and desire to maximise the efficiency of their responses and increase their contribution. This was also seen as minimizing preparation time, thus making the collaboration more successful. Thus, it is not surprising that eighty per cent (80%) of the students stated that *familiarity of the topic* was one of the significant factors that must be considered for enabling collaboration in RALs. Moreover, some 70% of participants expressed that the *relationships* between students were one factor that had an impact on collaboration. Approximately seventy per cent (70%) of the sample indicated that the relationship between participants is one of the essential elements to be considered when planning collaboration in RALs. They noted that the development of good relationships in RALs could increase the success of collaboration and learning. It was noted that overcoming shyness helped create a friendship and, in turn, made the activity more comfortable. Participants perceived that building strong relationships among the team members not only made a significant contribution to facilitating tacit knowledge transfer and collaboration, but also helped develop interpersonal skills. Almost three-quarters of the students (70%) were also discerning in their highlighting of the nature of the 'task' they were involved in as being an essential factor in helping their learning in the RAL environment. As with the results of Brindley et al. (2009) and Gibbings (2014), their responses indicated the need for clear instructions regarding the group task roles and responsibilities, consideration of timelines, and providing students with the best opportunity to focus on collaborating to share ideas and the workload. They also advised on the importance of the structuring of the approach to the task to stimulate the group members' thinking and talk, rather than leaving them to spend a great deal of time trying to clarify the task to develop a shared understanding.

In relation to the group members being able to successfully be engaged in dialogue together, again the majority of students (70%) identified *culture and background*, and *language and accent* as significant factors that need to be considered for successful collaboration and learning in RALs. They noted that students from different cultures and backgrounds can increase and improve their knowledge of other team members' perceptions and how they think since they bring different experiences and views to the problem-solving and discussion. For example, it was noted that those from diverse backgrounds may bring different methods to solve the problem at hand, thus fostering opportunities for their peers to increase their collaboration and critical thinking and focus on the task. This can be an added stimulus in the learning context, since groups from the same backgrounds and culture may tend to maintain the status quo within the group, depending on the design of the task and role of the leader. In this research, the leader's role and guidelines provided some opportunities to help team members to critically think about the Voltage Divider Experiment and the manipulation of the variables.

In addition, the students' language background was raised as an essential consideration in designing RALs. In the present study, sixty per cent (60%) of students noted that being open to and being able to understand students from language backgrounds other than English (the language of instruction in this case), is better able to promote collaboration. However, *differences in accent* were also raised as having the potential to create some difficulty in communication. Some students intimated that it is not always easy to understand the accent when fielding different ideas or trying to grasp another student's meanings. Therefore, this issue may also make collaboration more complicated, possibly impacting more negatively in the RAL environment when there may need to be more 'wait time' needed during students' turn-taking in the conversation. This adds to the findings of Kim and Bonk (2002) where students from different language and cultural backgrounds were found to vary in their levels of participation.

Management of time in the RAL learning environment was also raised as a vital consideration by the majority of students (70%). This also included the need to be aware of students who may be residing in different *time zones,* since if their access was required at a difficult time for them (e.g. very early morning or very late at night), their level of participation could be affected. Moreover, the more the process of the intended collaborative learning session is carefully designed, managed and equipped to guide and facilitate constructive communicative interactions, the more benefits are likely to emerge since there will be timesaving without comprising the activity. If the time is not managed well, then it will waste time and effort of all involved. The present research showed that collaboration is well supported when a team member or leader has the responsibility to manage the time and be sensitive to the quality of discussion and able to facilitate the different points of view of group members.

As noted earlier with respect to the importance of the quality of the communicative interactions and the role of the leader, almost three-quarters of the students highlighted how *questions* that were asked during the session comprised another critical factor in ensuring collaboration and collaborative learning in RALs. Questioning techniques were identified by the students as an indispensable factor for helping prompt the conversation to revise and gain new ideas and test out solutions to the problem of the Voltage Divider. Understanding how to formulate questions was seen as key to being able to help the group at different points to focus and improve their thoughts and opinions and increase the discussion and, in turn, the collaboration. However, the majority of students (70%) also pointed out that if members of the group brought a different *experience* to the RAL learning experience then the opportunity for adopting collaboration in RALs would be more limited. Thus, they believed participants should have enough background experience and knowledge to manage both the content to be learnt and the new technology for the collaboration to be successful. In this research, participants reported they enjoyed a pleasant experience that helped them perform well, and they felt there was effective co-operation, which made the activity more comfortable. They saw effective cooperation as contributing to a stronger foundation for collaboration and, in turn, made the leader’s role easier.

Related to this was the fact that sixty per cent of students identified the need to build *trust* in the group. Trust was seen as a crucial factor when considering whether to adopt a collaborative pedagogical approach in RALs. Humayun and Jhanjhi's (2019) and Rybnicek and Königsgruber's (2019) research also documented how positive trust has an impact on the success of the collaboration. For example, when members of the group have trust in each other this can strengthen collaboration between them, and at the same time reduce the possible issues and stresses that may occur if there is a lack of mutual trust. Thus, when there is mutual trust, this can eliminate any extra time and effort required to resolve difficult issues that would typically emerge from a more competitive context for learning. Teams with high trust are much more likely to collaborate within their group to make the effort to solve problems arising from different members' views, which is about enhancing learning. This outcome implies that although trust may not be directly related to team performance, it may affect team performance by interacting with many other aspects of team operations, such as communication conflict, trust, and commitment to the task (Shuffler, Diazgranados, Maynard, & Salas, 2018; Webber, Detjen, MacLean, & Thomas, 2019). Although trust was not positively associated with the team's performance, it should not be a reason to neglect its role in facilitating the performance of a capable team. In addition, if the RAL learning experience is an assessable task then it is even more important to ensure the design of the assessment does not create competitiveness but, rather, is able to support collaboration and collaborative learning. Although there have been claims that working in virtual teams can produce additional challenges due to the lack of social cues and trust that may come from others, Nurius and Kemp (2018) and Reina, Reina, and Hudnut (2017) indicated that any such absence does not necessarily impede the development of trust, although it may prolonging the trust-building process. However, when a sense of trust is created between group members this can result in the free exchange of ideas, thus forming the basis of a good relationship of trust and respect that, in turn, can help address any issues and ultimately enable collaboration. Moreover, the importance of trust to successful teamwork is equally applicable to non-virtual learning and workspaces as are the interpersonal skills and questioning techniques this research found participants required. Thus, this reiterates the relevance of successful collaborative learning in RALs to such higher education students' need for employability skills and the soft skills that are currently receiving more recognition (Jerome & Antony, 2018).

Although less than half of the students (40%) highlighted how important it was for the RAL learning experience to ensure a *topic interest* was considered that could best foster collaboration in the RAL, this was a highly relevant contribution. They advocated for an exciting and positive topic, explaining how it would gain students' attention and potentially increase both positive behaviour and the possibility of collaboration and, ultimately, improved results. This also related directly to their advice to *make the group task relevant for the learner*, in keeping with a research by Curtis and Lawson (2001). They found that the more interested students were in a group topic, the more they were motivated to participate in the collaborative learning experience. While this is not surprising, it is still an important consideration and valuable to know that the participants in this study critically reflected upon their RAL experience in such away. Allowing learners to pursue topics according to their mutual interest is seen as fostering their sharing of information and co-construction of knowledge. As Lin (2008) points out, authentic, real-world environments and relevant content can help motivate collaborative learning. As well, enabling students to have some autonomy in their learning, where they can control and direct it to a great extent, can help them to better understand the purpose for learning and relate it to their specific needs in alignment with their ZDP (Vygotsky, 1987).

Additionally, the findings of the research indicate that for about thirty per cent (30%) of the students a *fun environment* was recommended with regards to the design of the RAL learning situation. This was argued to be a factor in promoting students' collaboration and vital to the adoption of the collaborative learning approach. The participants advised that with such an interesting environment there could be both saving of time and cost-efficiencies that would help make collaboration possible and increase team members' attention to the task. This also relates to twenty per cent (20%) of students noting that the learning situation should pay attention to ensuring students have an *incentive* to collaborative in RALs. They argued that one essential element is for the activation of all members to participate, including the provision of knowledge and social support, since, in their view, such support makes collaboration successful.

6.3.2.1.2 Factors to be considered in inhibiting collaboration

The research findings with regard to the challenges and issues that influence the adoption of collaborative learning in RALs identified six factors that were possible inhibitors. Inhibiting factors were seen as those factors that negatively affected students' ability to learn collaboratively in a RAL environment. These factors encompassed (1) technology issues, with a hundred per cent agreement of students, (2) time management (90% agreement), (3) language issues, (4) unfamiliarity with the topic (80% agreement), (5) leadership (60%), and (6) relationships, identified by 40% of students.

While *technology* was seen as an asset and essential for the facilitation of collaborative learning in RALs, it was also identified as a potential inhibiting factor. This was because, firstly, the RALs learning opportunity was totally dependent on access to the Internet and, secondly, it relied upon the technological tools of the Zoom conferencing system and the LabVIEW software to make the Voltage Divider Experiment available. The students needed to learn about the operation of the software and how to use Zoom and experienced some difficulties in using the program without the setup session. Although their experience was positive, they did become aware of the potential for delays in the process of communication because of an unstable Internet connection. This issue had the potential to affect the activity timeframe, making it longer and, in turn, causing some delays in the collaborative learning process. Thus, Internet connectivity was identified as the most basic but profound issue to address when setting up strategies to promote online collaboration.

The participants also identified other factors that affected Internet connectivity, which included Internet speed, availability and reliability. These issues related more to the capacity of students personal Internet connections where their *Internet speed* and bandwidth may be too little to sustain a quality connection for the duration of the session. Unfortunately, when communication and the collaborative activity experiences interference the ensuing unreliability interferes with the flow of the learning and understanding. Thus, the absence of a reliable Internet speed leads to poor collaboration and makes being a productive member of the group more difficult. Similarly, the participants' responses also showed that *time* including, *time management* and *time zone*, were also potential inhibitors to the adoption of collaboration and interaction in RALs. The students stated that *time zone* affects the effort and the energy that they can contribute to the collaboration when their time to meet is not during their usual day. This also resulted in challenging their time management and, as a consequence, this had the potential to impact on their success.

Effective time management can help students to achieve their study outcomes. With regards to the time zone, it was seen as essential to determine a time that is equitable for all team members to be able to maximise effort and energy. In confirming the findings of Bonk and King (2012), who argued that time zone differences present the greatest challenge of working in a virtual team and a collaborative environment, this research revealed the need to build students' capacity to learn in RALs in the virtual space. It makes a strong argument for the application of and a range of technology to support the collaborative learning situation, including making session recordings available to counter Internet challenges and the importance of developing learner autonomy.

Moreover, ninety per cent of participants not only perceived students' *language* background as an enabler of collaborative learning but saw the counter argument that when *language* is more difficult to understand (mixed languages, with different tones/intonation, and or accent) it can limit collaboration and interaction in RALs. Since language is the major communicative tool for students to collaborate, any interference, including different dialects, can result in poor sharing of knowledge and reduction in collaborative activity. As a result, *differences in accents* were perceived by participants as the main element affecting communication between team members. Hard to understand the accents when navigating different ideas or other meanings makes collaboration more complex and may have a negative impact on understanding because individuals may get the wrong idea about the concept of the activity. The different accents of team members may lead to a lack of understanding and errors in practice, making cooperation more difficult. Thus, both the leader and the team members need to understand what others have said in relation to the task in order to facilitate learning.

Unfamiliarity with the topic was identified as a major inhibitor in that without the prerequisite knowledge participants would be unable to participate as expected, while those who were prepared would be held up. This could also cause students to feel under pressure, resulting in a lack of or poor collaboration and learning. Although the participants in the study were from the faculty of engineering and included a focus on electrical, electronic, mechanical, mechatronics, civil and construction, they faced some difficulties because some had minimum theoretical information on the task such that it took longer for them to understand the concept initially. Thus, eighty per cent

(80%) of the students stated that *not being familiar with the topic* was one of the significant factors that inhibited their collaboration in RALs. Moreover, if participants are drawn from different disciplines, though similar, there needs to be a preparatory activity to bridge the gap before collaborative learning begins. Ensuring continuity in learning is sound pedagogical practice whether teaching online or not (Laird & Garver, 2010).

With regard to *leadership*, some of the students stated that choosing an appropriate leader was one of the significant factors for successful collaboration in RALs. Also, if a leader fails to achieve collaboration or fails to make the activity and teamwork challenging this may be the result of not choosing the right leader who has the expertise to managing the dialogue and organise the meetings. Leaders should provide a supportive, collaborative learning environment by encouraging team members, outlining clear objectives and goals, offering appropriate resources, providing opportunities to view examples, and structuring a clear and well-organised instruction. This also has implications for the design of the learning task and learning activity since the present research ensured that the leader had instructions to follow that supported the collaborative approach. These results also align with the findings of Lee, Srinivasan, Trail, Lewis, and Lopez (2011) and Xie, Di Tosto, Lu, and Cho (2018), which established that students' perceived leader support was significantly related to their overall satisfaction. These results build on those observed in earlier studies, which found that students preferred having a leader to monitor, guide, focus, and encourage participation in their group and, if necessary, bring them back on task and facilitate their collaboration (An, Kim, & Kim, 2008; Kim, Wang, & Ketenci, 2020; Maushak & Ou, 2007).

6.3.2.1.3 Difference

Concerning difference, students perceived that different people with different perspectives bring various opinions and inputs to their RAL discussions, which was an essential and significant factor in influencing positive outcomes and enriching their experience, as they understood that everyone has a different perspective. As the activity group came from different backgrounds and cultures, it was found to be beneficial to draw from other people's knowledge and understanding in the group.

Most of the students mentioned that the differences helped them to make the collaboration occur, despite some having concerns that variations in accent might reduce the collaboration. However, the leader was found to have helped alleviate this obstacle of differences in background, values and experiences, opinions, thinking, understandings and inputs. Consequently, students mentioned that these diverse backgrounds and experiences led to different views, thinking, and knowledge being accepted, which they considered essential for their learning processes during the collaboration activity. The students stated that different backgrounds, a different understanding of the same information, and the problem-solving method increased their collaboration; and they also believed the leader's supportive role in this process was essential to their learning.

6.3.2.2 Element 2 - Quality of interactions

The second element of successful collaboration highlights the need for the students' interactions to be of high quality, meaning that the student dialogue should be focused on the task and allow them to critically reflect on the challenges involved in the problem solving associated with the Voltage Divider Experiment in this research. The students in this present study indicated group learning was based on the sharing of information and resources and involved promoting the questioning of each other and explaining, confirming, acknowledging and challenging knowledge. Students considered that sharing in the learning helped to develop their personal understanding and learning. Most of the students reported they learnt most thorough questioning and explaining. This process depended on the preparation of the learning task and the way the RAL session was managed. The students noted the importance of supporting information and being able to organise their ideas and test them within the group, thus enabling them to be challenged. It also enabled the identification of any gaps or misunderstandings and provided an opportunity to modify and reshape their ideas. Draskovic, Holdrinet, Bulte, Bolhuis and Van Leeuwe (2004) state that the task-related interactions should positively affect students' knowledge acquisition, but only if they lead to knowledge elaboration. The present research findings support this in that the task design, including the role of the leader, was able to foster this component. The process of collaboration is considered an 'interactive' process that enables students to communicate and interact to reach a common understanding among the group

(Dillenbourg, 1999). Vygotsky (1987) argued that social interactions are central to students' cognitive development. The interactions between the students and their exchange of ideas stimulate students' thinking/critical reflection and this is necessary for them to respond to the challenge of the experimental task. At the same time, they experience the context of cooperation which, again, contributes to the skills students will require in the workplace. The social interactions involved in collaborative learning also help students to understand their importance in being able to achieve a higher level of knowledge building than the traditional learning experience of information transmission (Chandler, 2017; May, 2011). This, in turn, may help to increase students' awareness about the role of communicative interactions in their capacity to improve their learning in the context of this pedagogical change.

The results of the current study clearly confirm the theoretical bases of learning in collaboration as regards Dillenbourg's element of need for quality interactions. This consistency between the visions of the students and the theoretical basis for collaboration indicates that the students were able to perform collaboration activities as designed. These results suggest that encouraging collaboration in RALs can work well, especially when the students are aware of the role of these interactions in their learning. The results also highlight the importance of maintaining and explicitly supporting the various types of communicative interactions in collaboration in RALs. The interactions observed in this research, which involved synchronous communication in the RAL environment, provided deeper insights into the communicative skills that students require to participate most successfully. But it can also be appreciated that as a pedagogical approach implementing collaborative learning can help develop and practice students' collaborative skills, which can add value to their future work needs. The research raised the issue of how higher education might address the call for embedding the soft skills in learning which are necessary for contemporary workplaces. The task design and interactive strategies in the present research were able to facilitate students' leadership skills, communication and interpersonal skills, problem-solving and critical thinking skills to negotiate solutions as a team. The most frequent sub-themes raised by participants with regards to promoting interactivity in RALs are discussed next in terms of supporting and assisting others, sharing and exchanging information, teaching and trusting others, helping others connect to past and present learning, discussing, questioning, explaining, challenging others, and confirming and challenging knowledge.

6.3.2.2.1 Promoting interactivity

The respondents reported that *supporting and assisting others* as part of their role as participants had a positive impact on the collaboration, they experienced in the RAL. They saw this as enhancing their own collaborative capabilities. This was despite unexpected problems that arose during the activity, for instance, when a student did not understand the sample and needed to learn how to add or subtract to make the resistors as minimum or maximum on the figure. The support that occurred gave students the confidence to ask and discuss these factors, so that collaboration was enhanced during asking and answering time. This willingness of participants to share their opinions and help in knowledge transfer and understanding the concepts involved in the experimental task was said to make learning easier for those students who were less outgoing or knowledgeable. In doing so the students also reported how they *shared and exchanged information* to clarify group members' understanding of the activity, which was essential to facilitating their learning and successful collaboration. They valued this type of interaction because it presented the different perspectives of their peers, which included comments on the participants' 'pleasant attitude' and the 'friendly atmosphere' of the learning situation. It was felt that all participants understood the activity and gained good knowledge from their peers owing to information sharing. Also, they noted that they received information quickly and easily during their interactions. Moreover, it was felt the team helped create a bridge of *trust* between members through their willingness to exchanging ideas and assist—which resulted in positive interpersonal relationships—the solving of the experimental problem, and the co-construction of knowledge. It was suggested that the collaborative process was able to provide students with a significant increase in knowledge in a relatively short time, which enables the group to move to the next step more quickly.

The students also described their role as one that included *teaching others,* which was seen as a valuable feature of learning in this way, although contrary to the traditional teacher-centred learning situation where students would be passive in the learning situation. In the collaborative context, these participants were provided with more autonomy in their learning, which motivated them to contribute to the group's goal in solving the experimental problem. Also, the research showed that the different levels of skill of each member (e.g. background, laboratory experience, work experience) can result in a variety of expertise within a group, such that the range of input into solving the problem can strengthen the collaboration and enhance the skills of all team members. Participation in the research task demonstrated to participants that helping each other in the learning situation enhanced their existing knowledge and corrected misconceptions in a supportive way.

Moreover, *helping others connect past and present learning* was also perceived as a benefit of the collaboration through the ongoing sharing and transferring of information between different participants. This was highlighted by other students assisting them to understand new concepts. It was noted that if there was unclear information, or students had a gap in knowledge, one of the other team members could provide explanations to make it more understandable. Thus, such opportunities for *discussing* with others promoted the value of collaborative interactions between participants, as well as facilitating new ideas and knowledge construction. Similarly, the role of *questions* and providing *explanations* was raised as additional critical factors found to be essential when considering whether to adopt collaboration in RALs. Seventy per cent (70%) of the participants thought questioning was an indispensable factor in the revising of ideas and gaining new ideas. Answering questions to help each team focus and raise follow-up questions were seen as crucial to helping students improve their thoughts and review their opinions and increase discussions and collaboration. The importance of students being able to provide an *explanation* in relation to the problem at hand was also raised by participants as necessary and formative to their learning. When questions or misunderstandings arose there was the opportunity for participants to explain, thereby providing a clearer understanding of the task or solution. Also, spending more time to explain and have the chance to ask questions to clarify and explain the theoretical background or the technical content was seen as supporting learning and, therefore, making it more comfortable.

Although the group work in the RAL required cooperation between participants, the promotion of collaborative interactions was also seen by the participants as involving *challenging others*. They pointed out the importance of challenging knowledge in order to critically reflect on the task and at the same time motivate their peers to interaction. Also, they recognised that every team member needed to contribute their knowledge to others, and their dialogue and discussion should be shared. All team members reported they experienced some challenges in their learning, however, they believed it allowed them to test the credibility of their knowledge. Likewise, the participants believed that *confirming challenging knowledge* was a vital part of their learning, which the collaborative approach was able to facilitate. They stated that dealing with information was one of the central key elements to promoting interactions with each other during collaboration in the RALs activity and the interrogation of the task/problem and discussion sessions. They argued that gaining other opinions leads to obtaining a better result compared with studying alone because different types of thinking have been taken into account, which can enhance learning and allow the building of new knowledge. These combined features were seen as building confidence and skills while helping to understand and solve the laboratory task.

6.3.2.3 Element 3 - Processes

Dillenbourg’s third element draws attention to the processes involved in the collaboration. Ideally, they need to be supportive of fostering opportunities for learning collaboratively. It was pertinent that the students were aware of the benefits of contributing different views through their activity in the RALs and they showed some sensitivity to the social interactions. However, behaviours of members of a team may negatively affect the situation if there is conflict and students lack conflict management knowledge, which requires a sophisticated level of interpersonal and negotiation skills. While the present collaboration was conducted for research in the real-life situation, whether for study or work it is more likely that some conflict may arise. Specific to the higher education situation, the presence of dominant students would reduce opportunities for constructive discussions and cooperation, particularly when collaborative learning is associated with competitive assessment. Even having to contend with differences in views may increase tension if this is seen as an obstacle to completing an assessment task early. In addition, feeling insecure to participate and challenging the differing opinions of the dominant students may prevent constructive discussion where students may be forced to accept the central student opinion without resolving differences in ideas regarding other learning processes. Thus, in such situations, there may be increased competition at the expense of cooperation. In turn, this can prevent the positive management of the leader when having to deal with different, strongly presented points of view unrelated to the learning goal.

In the present research, the students reported that the team did not experience negative impacts in this regard and accepted opinions with respect. Moreover, the relationship between the students could be described as excellent; they accepted a different point of view, and the participants listened to each other's point of view with respect. Also, it was notable that the fact that the participants came from different nationalities seemed to help improve and support cooperation. The trust built between team members as a result of their close communication and exchange of ideas formed the basis of a good relationship of trust and respect, which helps in overcoming obstacles and enabling cooperation to be realised. Johnson and Johnson (2013) believed differences in views can be constructive if the environment is open and the group is cooperative rather than competitive. This means students need to feel safe to share their opinions, ask questions and discuss their divergent views.

While the research task design addressed the way the collaboration could be best promoted through the structuring of roles and responsibilities, including the role of a leader, having a collaborative framework that makes explicit the range of communicative and social skills involved would ensure better strategy training for dealing with conflict management. This would also be relevant to students’ needs once in their future workplace. Thinking processes were an essential theme that emerged from the research with regards to the approach to learning when considering adopting collaboration in RALs. Processes such as problem-solving and knowledge transfer are important because the collaborative activity is typically based on learning essential knowledge and skills and being able to understand the thinking and sharing of thoughts of others so that one can accept or reject others’ opinions by offering a logical explanation. All the respondents mentioned that this factor could be regarded as a skill in enabling collaboration. In response to these changes, students noted they actively thought about the information in their minds to process what they were learning. But they had difficulty explaining related learning processes and suggested their thought processes were not available ‘in the front of their minds’, making it difficult to be precise. However, the students emphasised that their performance of these operations was carried out subconsciously. As these thought-related learning processes were supported by the actual technology with the Voltage Divider and their ability to manipulate the variables, the students could connect their thinking to the practical experience. This process helped them to understand the relevant details and conceptualise the ideas before discussing with other students. Additionally, students mentioned their thought-related learning processes as being related to listening to others' interpretations and comparing and linking any new information to what they already knew. This provides some evidence that students were aware of their learning and, in keeping with the theory of ZDP, the task was reasonably demanding for their level.

Generally, the students in this study expressed appreciation for the opportunities and the existence of a conflict in knowledge-related discussions and being able to analyse concepts from different points of view. In addition, they preferred to discuss topics that were associated with differences in views that were more challenging. These results showed that the students had come to understand what was involved in the process of learning collaboratively in a group compared with their prior traditional experience and appreciated the results. The students in this study were aware of the crucial processes to ensure collaboration and the role of these processes in developing their understanding and learning collaboratively.

6.3.2.4 Element 4 - Outcomes

Dillenbourg's (1999) fourth element of collaboration addresses the key area of outcomes. It considers the effects of collaborative processes and learning activities. Several effects of learning in the collaborative context were identified from the students' perceptions of their experiences during the research. These findings addressed the research question about significant benefits to students and institutes that can emerge as a result of adopting a collaborative approach to their learning. Besides, these findings also enabled an improved understanding of other findings derived from other data collection regarding student collaboration in RALs. Thus, this section responds to the third research question (RQ3): *What are the actual significant benefits of adopting a collaborative approach to the RALs?*

Based on the interviews, student reports on the RAL task, participant observation and the session video recordings, the findings demonstrate that the students held very positive attitudes towards collaborative learning and the RALs environment. The analysis of the significant benefits of adoption of collaboration in RALs was presented earlier in Table 5.6. This table showed the breakdown of eleven benefits for the adoption where the main anticipated benefits were identified as: Cost reduction; Time-efficiency; Remote access to Lab learning; Support and assistance in learning; Sense of reality (hands-on experience); Opportunity for group work; Effort reduction availability; Reduction of laboratory infrastructure; Increased student participation; Skills improvement; and Reduction of the level of risk in Lab work.

In terms of the impact of knowledge building, the study showed that students appreciated collaborative learning in RALs in relation to a new learning space, the learning processes involved, and the identification of benefits that included more exposure to different viewpoints through the structured group members' discussion. They considered seeing the problem from a different angle was conducive to building their knowledge through interaction with peers, which allowed them to understand problems from different perspectives. Likewise, they appreciated their participation in having to critically reflect and explain their think with peers. These interactions served as a learning medium and provided them with positive learning outcomes in successful learning with the Voltage Divider.

Students generally recognise that learning in collaboration in RALs was useful and valuable for them, especially when all group members were prepared before working in the RAL. They believe the collaborative process saved time later and kept them focused on their tasks compared with learning individually in the traditional setting. The positive effects reported by students include extending their knowledge and thinking, enhancing a range of high-level communication skills (including questioning, explaining and negotiation skills—which are consistent with successful collaboration) and the use of the technology in RALs. However, the students identified some negative issues related to their experiences in collaborating in RALS which may contribute to the potential uptake in the future. Specifically, some students noted that in some cases, their group did not work very well together. For example, they found that if students were from different regions, or did not have the same level of experience to bring to the learning situation or were unfamiliar with the conference software tool, the attempt to learn as a group was considered a waste of time by those who considered themselves more knowledgeable in these respects. Some students saw the situation as less productive with weak collaboration. This was in spite of the structured role of the leader and it presented the leader with a more challenging job to promote positive constructive dialogue about the task. As a result, the negative effects of experiencing adverse collaboration led to a feeling of loss of control in learning. In contrast, students who experienced a more positive experience considered their learning was enhanced and they felt they had some control over the discussion in their group as they had the background knowledge to contribute. Thus, a collaborative approach that provides students with some control over their learning and ensures they are prepared (e.g. taking to account their ZPD) should have a more optimum effect on the group dynamics and is more likely to increase students' motivation for teamwork.

Overall, students were appreciative and accepting of their collaborative learning experiences and were able to discuss the benefits of collaborative learning in RALs. From an institutional perspective, the students believed that the use of RALs could ensure *cost reduction* since the approach offers low start-up expenses owing to being online and not requiring the on-campus maintenance of physical laboratories when not in use. Similarly, there are costs savings for students who do not need to travel and be accommodated on campus and perhaps experience loss of learning at the same time. When the usage-based pricing model (Chirikov et al., 2020) is applied, start-up organisations can use collaboration in RALs to help them decrease their capital expenses. It also provides direct access to a shared laboratory or simulation, and new and small universities alike can launch new operations quickly with little to no upfront capital investment by sharing such infrastructure. A further advantage is that students can collaborate any time anywhere and there is also *flexibility* for staff to work from a range of locations. In addition, the ability to record the sessions and view them later potentially adds to the depth of learning. Using conference software or any collaborative tool from the onset can lead to a reasonable reduction in systems maintenance and updating requirements. In this research, ‘cost reduction’ was the first benefit of collaboration in RALs, as defined by the interview responses, to reduce the costs of students’ travel by facilitating online learning. Fifty per cent (50%) of the sample supported this perceived benefit. Participants believed that collaboration in RALs could bring a reduced use of physical hardware systems, which could add further savings for universities. Participants had very similar views on how the university might benefit by saving costs and managing their finances in order to ensure productivity and sustainability in the long run. This benefit confirms the result of studies by Elawady and Tolba (2009), Balamuralithara and Woods (2009) and Tomasik, Berger, and Moser (2018). In addition, this approach could be shared with other institutes and the cost distributed to improve profitability.

The study also found *time efficiency* was another vital advantage that emerged through adopting collaboration in RALs. Sixty per cent (60%) of the sample indicated this as a benefit since all data and information are stored in one or more sets of locations and can be revisited easily for revision of learning. A further benefit and efficiency were the facilitation of *remote access* where half of the sample made it clear that the adoption of collaboration in RALs could improve learning in rural and remote areas and internationally, given reliable Internet. Again, in this regard, considerable advantages were seen in reducing travel to perform laboratory work; and expanding access to learning and the attainment of new knowledge for those who cannot attend on a university campus.

In relation to the student experience, the theme of *supporting and assisting others* emerged from half of the students' responses. They indicated that supporting and assisting others was a vital part of achieving a positive outcome when collaborating in RALs. Based on their responses, providing this support was seen as enhancing the capability of collaboration, despite unexpected problems that may arise during the activity. Sharing in the transfer of knowledge was seen as making it easier to understand the concepts involved and better assist students in need.

In addition, having students gain *a sense of reality* was found to be one of the benefits that emerged. Fifty per cent (50%) of the sample stated that collaboration in RALs can give a sense of reality, which is important as this is often an issue that emerges in relation to moving from face-to-face learning to virtual learning online. Thus, this can empower the RALs system as an option. Achieving a sense of authentic reality involves students using video audio communication (conference tool) to see and communicate with their co-learners and pay attention to following each other's steps at the same time. Confirming this sense of reality from the participants' perspective in relation to the RALs experience is important for its uptake in the future. This research therefore found that facilitating a feeling of realty was an important benefit that emerged with the adoption of collaborative learning in RALs, confirming outcomes of the study by Deniz, Bulancak, and Ozcan (2003).

Opportunity for group work emerged as another benefit associated with collaborative learning in RALs. Half of the participants believed that having the option to learn as part of a group within the online laboratory was seen as assisting them to better understand the Voltage Divider Experiment and provide multiple ways of addressing the questions that arose. Also, the study found that forty per cent (40%) of the participants agreed that *effort reduction* was another benefit. This meant that participants perceived that by utilising collaboration in RALs, they saved time and effort by working with other more experienced or knowledgeable team members, whose discussion and responses provided advice and clarification. Forty per cent of the sample also identified the *availability* of data access and the RALs learning environment, and the fact that the sessions could be recorded and revisited was another major benefit. The participants believed that good internet access can provide ease of use for universities to have online laboratory tuition and a collaborative approach could be adopted. Similarly, the availability of learning in RALs adds an advantage for the delivery of higher education to a greater diversity of students and enhances the delivery of current practices as noted earlier in a more economic, yet effective, way. An additional advantage for the adoption of collaboration in RALs recognised by the participants is the *accessibility* feature. Again, the Internet was considered the backbone of the utilisation of the computing services and this was seen as allowing students whose residences are not within daily travel distance of a university to engage in education through such online learning, particularly with regard to engineering where LAB work being on campus can present a stumbling block. Furthermore, approximately a third of the participants believed that the RALs experience *increased participation* within the group. This was reinforced through the dialogue that transpired during the collaborative activity. Participants were of the opinion that students would be less likely to misconstrue information when learning collaboratively in the RAL.

Improving students' skills was also identified as a benefit, but only by twenty per cent (20%) of the sample. These participants viewed the RALs collaborative experience as improving communication and the quality of dialogue in the learning situation, as well as understanding of the content. They also mentioned they developed more sensitivity to language and culture, and they felt there were more positive attitudes towards peers and their learning. It was suggested that collaboration in RALs can also correct some misconceptions and broaden students' horizons and encourage students to be more active in the collaboration process—which is crucial for their future in engineering.

Finally, *reducing the level of risk* was seen as a major advantage of delivering LAB work through RALs. However, as important as this issue is, this was only raised by ten per cent (10%) of the sample. Nevertheless, this is an important observation and recommendation for the adoption of RALS to deliver Lab work. This can effectively reduce human danger and injury when attempting high-risk experimentation. A reduced level of risk can lower the risks and associated costs for individuals and institutions. It also means students can access remote or dangerous areas without risk, for instance, high-voltage electrical circuits are safer compared with hands-on, which is desirable in reducing any associated risks.

6.3.2.4.1 Positive attitude

Overall the participants showed a positive attitude to the RALs collaborative learning experience. They indicated that this experience was beneficial to their learning and resulted in a feeling of enthusiasm for the changed approach to pedagogy. They saw it as providing an effective strategy that was able to clarify the task, which led to more discussion and improved understanding of the content through learning collaboratively with their colleagues. Additionally, they reported a positive experience with the laboratory work, such that the skills they acquired added to their knowledge and expertise.

The information was circulated through the team members and clarification provided for complicated parts. Gaining more opinions led to enhanced participant outcomes. The participants reported that the collaborative experience involved them in different types of thinking, which enabled them to better grasp the new knowledge. They noted that the experience provided added benefits of establishing good relationships with other team members. It was also said to improve self-confidence and open up possibilities for acquiring new knowledge. The experience of working as a member of the team was also shown to improve participants' attitudes to understanding new knowledge, as well as the different cultures and the language backgrounds of their peers. The collaborative context appeared to more effectively address participants' misunderstandings in terms of correcting some ideas and broadening their horizons. Students were positive about the features of the technology that expanded access to learning and the availability of follow-up though the RAL sessions being recorded for playback and revision. They were also supportive of the ability of the RALs environment to allow students to work remotely and access the laboratory component in engineering from anywhere where there was an Internet connection. This aspect was seen as crucial. Thus, the use of the technology was seen as being able to improve engineering students' opportunity for mastering LAB work through pedagogical designs that promote critical communicative interactions and reflection, and dialogue about the task. This model for collaborative learning in RALs also has the capacity to be developed for use in the industrial and vocational sector, where working and learning collaboratively requires a suite of skills such as the soft skills, as well as the technical skills associated with various use of equipment such as the Voltage Divider.

The collaborative approach was also seen as being able to save time and effort because the resource, the Voltage Divider in this case, was available online and did not require maintenance as with physical equipment available only on-campus. Obtaining information from different viewpoints was also seen as advantageous as it can make learning more accessible and save time and cost. Students made it clear that this experience can be conducted in other laboratories and for other topics. Also, the remote laboratory focused on electronic and electrical majors, but can be constructed for experiments in other areas for other students to gain these advantages in learning. The activity made students think about how they performed in this laboratory and how it offered different perspectives on the experiment and improved their learning.

However, if students have a negative outlook such as being unfamiliar with the conference tool or are generally uncertain about their use of technology this can affect the collaborative process by limiting the collaboration. However, it is important to note that in this research strength in the support of collaboration was the design of the approach to creating collaboration through paying attention to the structuring of the leader's role and responsibilities. Even though some students struggled a little because of the different fields of expertise within engineering, they still made good progress as the collaborative approach appeared to work for them in enabling them to participate. Although differences in language backgrounds were found to cause some participants to have difficulty communicating, this learning context was reflective of many of today's higher education diverse groupings, and many engineering students are international from non-English speaking backgrounds.

6.3.3 Doolittle principles of learning experience design

As a result of the analysis of the interview transcripts and activity recoding and observation of the RALs sessions and the student report task, these data showed strong evidence that the eleven Doolittle principles were operating in the context created for collaborative learning. This evidence is presented in Table 6.1, which provides a summary of the relevance of the Doolittle's principles to the outcomes of the research based on the students' perceptions. For each principle displayed in column one the table presents (1) a summary of how the principle was intended to apply in the study; (2) an exemplar student supportive response to show how the students' response confirmed the principle applied to their RALs experience; and (3) a brief explanation of the relevance to the research into collaborative learning in RALs.

Table 6.1

Summary of the Relevance of the Doolittle's Principles to the Outcomes of the Research Based on Students' Perceptions

The 11 Doolittle Principles	Summary of how the principle was intended to apply in the study	How the students' responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
1. Teach using whole and authentic activities.	As a whole and as an authentic cooperative learning activity learning through the Voltage Divider Experiment provided a way of exploring Kirchhoff's law and Ohm's law and how they work in practice in the real world.	*The idea came to me about controlling the devices remotely and collaborating with other team members after I had done it? I liked the idea very much because I felt it was real, and everything, I have done I have seen it with other team members doing it without any delay, and we did not imagine this technology before and how it feels like real and authentic*. (Y08).	From the participants' perspective, their collaboration on the learning activities was shown to be genuine, rather than contrived or artificial, even though it was conducted in a RAL.
2. Create a "need" for what is to be learned.	Once students understand the need for Kirchhoff's law and Ohm's law in the Voltage Divider activities it should have been easier to motivate them to understand the need for the calculations and measures and comparison of measurement values.	*If all team members get to get the benefits from the activity that makes interesting for each of them and is not just wasting time, and the performance will be high as well*. (O010).	The participants recognised that the collaborative approach helped to increase their motivation and had a positive effect, which reinforced the importance of them being able to see the need for learning activity.
3. Create classroom exercises that require social interaction with peers, parents, teachers, or professionals.	Each student was required to interact socially in both the calculating and the measurements actions with their peers and the leader in a small group of 3 or 4. This social interaction was designed to allow them to exchange ideas and experience new behaviours and, ultimately, through the	*There was a high level of effective collaboration and interactivity during the learning activity as well, team members, who had less understanding, took the advantages to ask for help to make the task more understood*. (Y08).	The design and structuring of the collaborative activities were shown to have successfully fostered the desired social interactions between group members.

The 11 Doolittle Principles	Summary of how the principle was intended to apply in the study	How the students’ responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
	collaborative dialogue express themselves and absorb the new ideas.		
4. Encourage self-talk or egocentric speech.	The design of the Voltage Divider Experiment learning activities aimed to stimulate participants’ interactive talk and at the same time, it involved them in problem-solving through the manipulation of the variables that should in turn have provided them with the opportunity to think and employ self-talk or egocentric speech.	*We can put any value of resistance and we can see what happen for the voltage and everyone can see that from his computer at the same time. (R04).* *So, I think this is the second step and it is sufficient just to show how to control so that I can show what we have done this before. (Y08).* *So, if you can change the value of resistor you change the voltage in each resistor, and I think in the second case is the case of maximum and minimum so you can focus in the voltage in one resistor. (O010).*	In spite of the Voltage Divider Experiment design and the leaders’ promotion of the collaborative interactions and need to think about the problem and the issues involved, they tended to not provide sufficient time by moving on to talk with others. Thus, this aspect presents a greater challenge for the design of the learning experience and requires some refinement to the leader's instructions and understanding of how the successful application of this principle appears in practice. Often leader discourages team members from self-talk by stating thinking to yourself then interacting with others. while the students are involved in the Voltage Divider Experiment, allow for and even foster self-talk as a legitimate problem-solving tool.
5. Provide opportunities for verbal interactions.	The task and learning experiences using the Voltage Divider Experiment were specifically designed to promote verbal interactions between both the leader and team members and between the team members.	*Also, if there were unclear points, there was a real-life and voice communication conference tools available so you could ask any member or discuss after the member had finished his duty.* (Y08).	The analysis of the video recording of the sessions showed that the participants took up the opportunities provided to speak with each other and understand each another's thinking.

The 11 Doolittle Principles	Summary of how the principle was intended to apply in the study	How the students' responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
6. Instruction or activities must precede a student's development.	In this study, students should have had some prior knowledge of the theories that underpin the Voltage Divider Experiment e.g. Kirchhoff's law and Ohm's law, but for those who were less familiar did not take on the leader role so they were able to be free to participate in the procedures to experiment, and ask questions to ensure they fully grasped the whole activity concept and though formative assessment assistance and final verification took place.	*The work was outstanding, and the team member was collaborating well which means we got the new fresh ideas, sometime during the activity discussion and asking questions from all members we got the new novel ideas; by answering those questions we could get a good collaboration and working team talent. Working as a team, the new idea and knowledge helped me to discover more and more*. (N06).	The research showed the importance of the leader's role and the skills required as they needed to closely monitor students' responses to the task requirements in the group and be able to respond to questions and be mindful of participant' discussion to ensure that each one was not only being sufficiently challenged but to determine if anyone was struggling to understand, and finally whether each had learned the intended material.
7.Present tasks that students can perform successfully only with the assistance	The research planned to construct a task that would be at the upper end of each student's zone of proximal development so that the student needed to develop in order to completely master it. The Voltage Divided activity prompted the team members' ability to think abstractly and predict results on the basis of them experimenting through the manipulation of the variables involved. The role of the leader included the provision of assistance.	*In regards to the activity it was to control in the remote access laboratory system - this was a definite idea and excellent to solve many issues that could not be done in the same time and different locations; it was challenging to perform it, by using collaboration by remote access helps us to communicate and solve the challenges and to control and manage a laboratory and take the result from the real laboratory from the Intranet.* (N06).	The research showed that collaborative learning tasks for RALs can be successfully designed to lead a student to develop new knowledge and understanding. It confirmed that tasks can be constructed to address each individual student's zone of proximal development in the group so that the student must develop in order to master the task. However, while differences in ZPD can be managed to some extent through the careful design of participants' roles and the task procedures and activities there is a need to be cautious with regards to any student who is able to do the task without assistance. This

The 11 Doolittle Principles	Summary of how the principle was intended to apply in the study	How the students’ responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
			raises the issue of formative assessment for tutors/teachers to be able to understand where students’ learning is at before planning the task, and also building this into practice (Habibi & Dashwood, 2020).
8. Provide sufficient support to enable the student to perform challenging tasks successfully, and then gradually withdraw support as the student becomes more skilled.	In this research the assistance provided for the Voltage Divider Experiment took several forms. This was managed through the task design, which was structured through the enabling of the collaborative approach that involved the role of leader. For the theoretical aspect when working on the mathematical calculations, assistance was in the form of direct instruction concerning the role of sample space, outcomes, and trials as they relate to calculating output voltage cross resistors relevant to Kirchhoff's Law and Ohm's Law. For the experimental practical processes, involving the identification and manipulation of the variables, assistance was available during the sessions from the leader and drew on the collaborative approach that encouraged participants’ questioning and discussion. For the	*Also, if the task starts from easy to hard, the collaboration will increase commensurately. If the hardest of the task increases the collaboration increases*. (Y08).	The research showed the importance of the design of the learning task being able to take into account students’ prior knowledge and be structured to allow them through the opportunity to collaborate to meet the learning objectives. By presenting activities that require the student to need some assistance, and making that assistance available in a supportive, collaborative approach, the activity will lie within the student's zone of proximal development, besides foster social mediation.

The 11 Doolittle Principles	Summary of how the principle was intended to apply in the study	How the students' responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
	technology considerations, instructions were provided to enable the participants to set up their computers to access the RAL.		
9. Students must be given the opportunity to demonstrate learning independently of others.	While the task design allowed the leader to provide assistance in the form of knowledge and organizational materials and time management for the Voltage Divider activities, the instructions to the leader gave a sequential approach to encourage participants' ultimate independent demonstration of having met the learning objective.	*The activity was laboratory-controlled, with some experimental or devices online or remotely, by working as a team to get the outcome and write a report after analysing the data achieved from the activity, with the possibility of switches to control the tasks through the members and give the members control, and doing their duties by themselves because there was one member had to control each time on this responsibility*. (Y08).	As the participants began to learn the task, for which they needed varying degrees of help, eventually they were able to take over giving them more responsibility to carry out the task independently. To achieve this the task design and the clarity of participants' roles and responsibilities was paramount and equally an essential consideration to enable the collaboration to happen successfully.
10. Construct activities that are designed to stimulate both behavioural changes and cognitive/metacognitive changes.	The task was designed to lead participants through a set of instructions that were sequenced to draw out the required understanding through the role of the leader and the roles of the learner to enable each participant to demonstrate their understanding. Giving each team member turns to complete independently also provided a method of formative assessment and then summative assessment for the leader to determine if participants had mastered the task at hand.	*This task teaches me that this kind of working helps in enhancing the existed knowledge or correcting the wrong thoughts and that is the benefit of sharing the knowledge in a group. (O03).* *I am able to put any value of resistance and we see what happen for the voltage and everyone can see that from his computer at the same time, it is a good refresh for my information about electrical circuits. (Y08).*	Following the Voltage Divider activities, and other group calculation activities, cognitive/behavioural changes became evident: (1) through participants 'questions and discussions with other team members during the collaborative learning experiences and (2) when participants were required to use the equipment to work out the circulation and measurements of Kirchhoff's Law and Ohm's Law and in their ultimate independent performance.

The 11 Doolittle Principles	Summary of how the principle was intended to apply in the study	How the students’ responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
		Collaboration with the team was easy and helped me to be involved in the activity as I had doubt and struggle to understand this activity for myself. I discussed it with the team members. This practice has helped me to understand the procedures and the task because the topic was new with respect to my knowledge. (M07). *Working as a team the new idea and knowledge helped me to discover more and more. (N06).* *This task teaches me that this kind of working helps in enhancing the existed knowledge or correcting the wrong thoughts and that is the benefit of sharing the knowledge in a group. On the other hand, getting more opinions lead to obtaining a good finding because you have been involved in different types of thinking. (O03).*	Activities should be organised to develop not only the ability to perform certain behaviours, but also the ability to plan, organise, and control behaviour.
11. Closely monitor student progress in order to avoid assigning tasks that are not within a student's zone of proximal development	This is closely related to principles 6, 7 and 8 for which the design of the Voltage Divider Experiment learning task and participants’ roles and responsibilities, including the instructions for the leader facilitated the ability to closely monitor	*Collaboration with the team was easy and helped me to be involved in the activity as I had doubt and struggle to understand this activity for myself. I discussed it with the team members. This practice has helped me*	The research showed that the selected Voltage Divider Experiment task was mainly within all the participants’ ZPD apart from one, where the participant was able to achieve the goal more speedily. It raised the issue of the challenges of designing learning

The 11 Doolittle Principles	Summary of how the principle was intended to apply in the study	How the students’ responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
	participants’ progress. It was ensured that the team members had some understanding of the nature of Kirchhoff's Law and Ohm's Law, and to be able to calculate various types of equations.	*to understand the procedures and the task because the topic was new with respect to my knowledge. (M07).* *In our case simply succeeding was the purpose of this work, to get the right information and discuss the different perspectives to gain a better level of understanding of the task. For example, some members struggled with every piece of information because they lacked some knowledge or had communication-based problems. These were solved through the help from other members in introducing, repeating and arguing for the right answer. (O03).*	experiences in general to meet this principle and for how to build in the enablement of collaborative learning in particular. It shows that a deep analysis of the task is necessary, along with knowledge of the kind of dialogue that indicates learning is collaborative.

6.3.3.1 Teach using whole and authentic activities

Such learning activities establish the authentic context that should reflect the real-life situation to provide learning more realistically. Achieving this is always a challenge in learning programs where the actual equipment or other resources or contexts are difficult to replicate in this way. When students are provided with the opportunity to engage in keeping with this principle it enables them to more closely experience the reality of the task which, in turn, can prompt them to think more about their learning. In many educational environments, there are limited opportunities for such engagement and reflection due to the lack of adherence to this principle, as well as when there is the absence of the opportunity for dialogue and collaboration in a more social context as would be the case in a workplace (Ajjawi et al., 2020). The experience in this research suggests that pedagogical approaches that do not allow students the opportunity to collaborate socially and to engage in meaningful discussions about issues associated with their problem-solving and learning are more limiting in ensuring the scope and depth of participants' learning. In keeping with this principle, this research task and activity design was also based on social constructivism in the implementation of collaborative learning (also applicable to principle 3). The task required the participant to work in small groups (up to five members) in the RAL. It also required setting up a major task designed to facilitate online collaboration to include many of the elements of authentic learning. All the respondents declared that they perceived the activity as authentic. However, the research showed that in order for RALs to adequately satisfy this pedagogical principle, the online environment must be reliable, and the task and activity design must be planned and structured to facilitate the planned outcomes. Participants also noted the importance of positive interpersonal relationships, the ability to allow for different viewpoints and competing solutions, the time to reflect and the need to seamlessly integrate the learning with the assessment.

6.3.3.2 Create a 'need' for what is to be learned

This principle was achieved through the task and activity design being relevant to the participants' interest area of engineering; although it is acknowledged that they were also participants in this research at the same time. Nevertheless, the results supported this principle as the participants' involvement and responses showed they were very much aware of the relevance of learning about the Voltage Divider experiment. In their collaboration in the RALs, the participants worked on the experiment according to the leader's guide, which led them through a sequence of activities to help them understand the theory they had studied in lectures and to gain a full understanding of the problem-solving/manipulation of the variables required in the experiment. Thus, while not many participants raised the issue of having a 'need' for what they were learning as being necessary to enable their successful learning through collaboration in RALs, the majority saw their involvement as beneficial and not time-wasting. It is also noted that because the participants' work was not graded and therefore the activity did not count towards assessment in their study, at the same time the collaborative approach meant they were conscious of their personal performance in response to the activities.

6.3.3.3 Create classroom exercises that require social interaction with peers, parents, teachers, or professionals

The research design of task and activities took account of this principle, and it is argued on the basis of the results that the participants were engaged in social interaction with each other. This social interaction allowed them to express and exchange ideas, and with the planning of roles and responsibilities and the involvement of the leader's role the interactive dialogue reflected their focused constructive responses. Their interactive responses provided insights into their thinking about the Voltage Divider Experiment operations and the issues involved and the importance of the leader's role in managing this. The research has also drawn attention to the need for participants to have acquired supportive interpersonal skills to work collaboratively with each other. Constructive social interaction involves good listening skills and both effective verbal and non-verbal communication skills. In addition, since the collaboration involved solving problems together and the sensitivity to support peers in their questioning, participants also needed to be able to negotiate and sometimes be assertive in keeping the focus, but at the same time be respectful to peers (Johnson & Johnson, 2013). Constructivists encourage the use of pedagogical approaches such as collaborative learning to enable students to develop as autonomous learners. Thus, in this research, there was evidence of the participants' use of some soft skills that contribute to learning independently. Besides communication, interpersonal skills and problem-solving, they were immersed in teamwork as part of the collaboration, which gave them the opportunity to reconsider their initial view and adapt their thinking in the light of new knowledge (Hughes, Bradford, & Likens, 2018; Jerome & Antony, 2018). Different levels of experience within the team were also shown to foster social interaction. This reflected a sense of teamwork in achieving the objective while taking account of individual views and the constraints of time (time management).

6.3.3.4 Encourage self-talk or egocentric speech

While the design of the task and activities facilitated communicative interactions and the participants' discussion in relation to solving the Voltage Divider Experiment problems it was difficult to argue self-talk occurred, although it may have been through metacognitive processes. Nevertheless, fifty per cent of the participants declared that they felt the activities required self-talk and that this was necessary for their successful collaboration in the RAL. In addition, this principle is in keeping with constructivist teaching and learning in creating learning contexts that support the construction of knowledge. Interactions can facilitate both organisational and problem-solving capabilities. As Vygotsky (1987) notes, the main purpose of talking self-talk, whether aloud or metacognitively, is to guide the student towards thinking individually. Vygotsky assumed that this process is the basis of learning and that expressing thoughts out loud with others eventually becomes internalized as part of our repertoire of problem-solving strategies. It is suggested that this use of language helps students to be strategic, rather than merely impulsive during the discussion, and so assists their approach to solving complex problems, as well as controlling their own thinking and behaviour. Therefore, this principle was supported by the research as being an important consideration in the design of collaborative activities.

6.3.3.5 Provide opportunities for verbal Interactions

It is clear that the design of the task and learning activities for the Voltage Divider Experiment facilitated verbal interactions between the participants, including the leader. The clarification of the roles and responsibilities and the structured guide ensured that these interactions fostered collaboration within the group having been presented with a problem to solve. As language represents the channel through which ideas and behaviour patterns become internalized (Bornstein, Hahn, & Suwalsky, 2013), the need to take account of it in task design would seem essential, yet the more traditional more monologic learning environments tend to foster a more transactional use of language (Heap, 1985). Thus, this principle also reiterates the importance of creating a conversation where ideas can be exchanged. Language allows for the construction of knowledge and cognitive skills. The language provides patterns of behaviour and facilitates the thinking and restructuring of mental functions (Gurzynski-Weiss, 2020). Thirty per cent of the participants mentioned that the facilitation of the group's verbal interactions was vital to their successful collaboration in RALs.

6.3.3.6 Instruction or activities must precede a student's development

Given that the participants were part of a research project this principle was taken into account through their selection firstly for their engineering background. In addition, the Voltage Divider Experiment was also selected as presenting a challenge conducive with their knowledge and skill to be able to further their learning. Thus, in keeping with this principle, collaborative learning activities should be designed to ensure students reach new knowledge and understanding. Tasks and activities should be constructed to build on students' ZDP wherein their capability can evolve in order to learn and control the task. The participants' responses showed they appreciated the need for learning activities that were able to stimulate their interest and build on their existing knowledge. They were of the opinion that fostering new knowledge and understanding through structured collaboration was central to successful LAB work in RALs. They also reported that they gained new ideas by discussing and asking questions between all members, besides learning from the different talents of their peers.

6.3.3.7 Present tasks that students can perform successfully only with the assistance

In order for the participants to master the Voltage Divider learning activities, the participants needed to first become familiar with the technology and set up the Voltage Divider simulation on their computer by accessing the Internet. They were also required to become familiar with the video conferencing application and also the task information. This began the learning journey, where through the leader's management of the learning activities and the participants' collaboration and mutual assistance occurred. Thus, the aim was to not distribute tasks beyond the current capability of the participants or withhold assistance, as that would likely lead to frustration. However, as the participants began to understand the experiment in which they were engaged their conversation reflected their ultimate independent mastery of the task.

6.3.3.8 Provide sufficient support to enable the student to perform challenging tasks successfully, and then gradually withdraw support as the student becomes more skilled

As with principle seven, this principle informed the selection of the task to ensure it would be sufficiently challenging, but at a level that was in keeping with their background knowledge and skills with room for development. Forty per cent of the participants reported that their learning in RALs was sufficiently supported initially to enable them to grasp the concepts of the Voltage Divider Experiment; and by the end of the session feeling that they had succeeded with their learning collaboratively in RALs. This principle also highlights the importance of the preparation provided to the leader and the suitability of the learning activities in ensuring that support could be provided and gradually withdrawn in the collaborative learning context. This was also found to help the participants gain a sense of autonomy and responsibility for their own learning as they were challenged by the experimental task. As their responsibility and interactivity increased, the whole concept became clearer as they were required to report the result and discuss it with their peers. As an activity online or remotely, the collaboration involved working in a team to solve the problem and write a report after analysing the data as they went along. Each participant was involved in the activity, using the switches to control the tasks and demonstrate their understanding.

6.3.3.9 Students must be given the opportunity to demonstrate learning independent of others

The vital goal of any collaboration learning activity is for each member of the group to gain the required understanding to implement every aspect of the activities and skills independently. This is in keeping with Kagan’s element of independent accountability as an outcome. For the participants to be able to have confidence in actively carrying out activities independently, the present task and activities were designed for them to experiment with support, but in the final stage to attempt the activity independently.

This ensured the learning included some formative assessment through the collaborative approach and the leader’s instructions. Given that the participants in this collaborative learning worked on the same task there was close monitoring of their performance by the leader, whose responsibility also included the summative assessment as to whether the student had mastered the task. However, only approximately a third of the participants mentioned that having the opportunity to demonstrate learning independently of others was necessary when learning through collaboration with their peers in RALs. Related to this was that participants felt that the overall worry of being successful in the learning was reduced when the information was shared, and each team member was required to contribute to constructing new knowledge through the activities—although ultimately there was individual accountability. Students also reported they made their own efforts to investigate more information. This accrued by asking each member's opinion or reviewing new ideas different from the central concept, which helped the teamwork and individual work successful.

6.3.3.10 Construct activities that are designed to stimulate both behavioural changes and cognitive/metacognitive changes

This principle raises the importance of designing learning activities that are organised and structured to develop students’ thinking about the task such that in tandem with this when learning takes place there should be a change in behaviour. In the present research, the learning activities were structured and led to facilitate the participants being able to manipulate the variables of the Voltage Divider Experiment to ultimately grasp its purpose and calculate accurately as required. As noted in relation to principles four and five, the structuring of the collaborative learning activities and the leader’s role helped to stimulate the participants’ thinking, which was evident to some extent in their collaborative dialogue and reinforced through their interview comments. Forty per cent of the participants expressed that they felt the collaborative learning experience caused them to think more about the task and solving the problem. Moreover, they saw this as enhancing successful collaboration in RALs. Thus, in keeping with a social constructivist approach adherence to this principle is seen as vital to students’ cognitive and metacognitive development, and co-construction of new knowledge. For this knowledge construction process to be complete, the student must not only build knowledge itself (through cognitive/metacognitive processes) but also acquire the necessary thinking capability to use that knowledge effectively. In this case, it relates to the purpose of the Voltage Divider Experiment, which also depends on the authenticity of the task in being able to relate to its practical use in the engineering context.

6.3.3.11 Closely monitor student progress in order to avoid assigning tasks that are not within a student's zone of proximal development

While closely related to ensuring principles six, seven and eight are met in the task and learning activities design, this principle was a significant consideration for the way the role and responsibilities of the leader were conceptualised in the present research. It meant that the leader needed to closely monitor the collaborative discussion that was prompted by the sequence of learning activities. In doing so, the leader needed to be sensitive to the verbal and non-verbal reactions of group members and constructively couch his responses while simultaneously evaluating where each participant’s learning was at in terms of reaching a stage of independent mastery of the task. This also reinforces the viewpoint that the role of interpersonal communication skills and other soft skills, as noted earlier, have been shown to underpin collaborative learning pedagogy. Importantly, just because students work in collaborative groups it does not mean they will automatically relate to the material which has been designed for their activity learning as these Doolittle principles show. Instructors need to be careful in defining the tasks and learning activities to ensure they are in the Zone of Proximal Development of each student, which means they need to have processes and appropriate data upon which to draw. Moreover, the participants showed their awareness of the need for their progress to be monitored in order to enhance their learning in the RAL. They were found to be keen to receive feedback on their performance and direction if they were not on the right track. The advantage of the online RAL learning environment was also found to include its ability to support ongoing monitoring while participants were working, and more easily allow progress to be deciphered, in addition to records that can be used in student consultation/feedback. In turn, this relates to the efficiencies that collaborative learning in RALs can contribute to higher education LAB work in terms of saving time, improving staff and student involvement, and even spawning staff pedagogical professional development as well as saving costs.

6.3.4 The research evidence for the addition of three new principles relevant to collaborative learning in the RALs environment

Besides the research being able to confirm the applicability of Doolittle's eleven principles to the teaching of LAB work in engineering through RALs, it was also found that there was a need to take account of three other aspects of the design and implementation of the collaborative approach to learning. The requirements for the participants to engage collaboratively not only highlighted the importance of the role and responsibilities of the leader and participants in relation to the structuring of the learning experience but also emphasised the need to create an authentic learning environment. Thirdly, the research identified that in terms of the facilitation of positive collaborative dialogue, participants need to have an awareness and use of the soft skills to ensure constructive conversations. These aspects emerged as key to the learning needing to happen through active engagement in the context of social learning and the use of interpersonal skills. These three new principles are presented in Table 6.2 and explained further below. They extend the task design considerations to ensure students can work together in a group or team as they would in a work environment. They also support the need for students to be able to engage in dialogue to help solve problems and create understanding and co-construct new knowledge more effectively.

6.3.4.1 Ensure the role and responsibilities of the leader and participants are sufficiently structured in terms of achieving the learning objectives of the task to facilitate positive leadership and enable effective collaboration in the RALs

In support of this principle, the students reported that the leader's attitude to their role and responsibilities in facilitating the group's collaboration and learning opportunities should include being patient, easy-going, able to deal with team members' different views and expectations, manage time and the dialogue effectively and be able to demonstrate social skills to communicate and deal with people from different cultural backgrounds. They emphasised that they needed to have a respectful manner, but also bring a strong theoretical background and practical experience of the topic, with the ability to analyse students' questions and hold the pedagogical skills to progress the collaborative learning proceedings. They saw this as including the circulation of the relevant information, the ability to control the learning experience through being able to multitask at the same time, clarify the unclear concepts, correct misinformation, support team members and break the silences.

Similarly, according to the interview analyses of participants' responses, participants were also of the opinion that for the facilitation of collaborative learning in RALs the skills of the leader should include the ability to first verify that each student has the appropriate access to the activity within the site link. The leader's role and responsibilities were also seen as being able to help students at the beginning to be familiar with the activity if they had difficulty understanding any information about the task. Thus, they concluded that the leader was the most vital person impacting on their overall success in learning, given that the task was appropriately designed for their learning.

Table 6.2

Summary of the Relevance of the Research Study's Formulation of Three New Principles

The 3 new Principles	Summary of how the principle was intended to apply in the study	How the students' responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
1.Ensure the role and responsibilities of the leader and participants are sufficiently structured in terms of achieving the learning objectives of the task to facilitate positive leadership and enable effective collaboration in the RALs.	The leader role and responsibilities related to managing and ensuring participants interacted collaboratively and ultimately independently completed the task. The leadership role also involved (1) encouraging the participants to participate, which required close observation of the individuals by listening, timely responding, inputting of information and evaluating/clarifying their responses e.g. questions, comments and observations, (2) checking that participants had the same opportunity to participate and (3) being sensitive to their discussion procedures and answers in leading each of them to discover success. As well, the leader needed to follow the guide to facilitate the participants' collaboration with each other in working out the answers and checking with each other to send the correct answers to the calculations, since the activity linked to each participant who had access to the RAL at the same time from a different location. Thus, the leader needed to be aware of the time, procedures and quality of collaborative	*The leader was doing excellent leading for the information received it and circulated it to all members and gets the information for their comment and their final point of view. In the beginning, the leader should have a strong background and theoretical experience for the topic and high social skills to ease communicate with the team members, ability for analysis the questions and passed them in the right way, also time and dialogue management are most important to make collaboration work well because shortness of time can be a disadvantage of teamwork without managing time. If the leader has a good experience and ability to manage these issues it easier for collaboration to occur. It also will save activity time (O010).* *In the activity we have done the leader should have the theoretical and experimental experience; time management was essential for the leader, and dialogue for management because sometimes there was confusion on point view or idea that the leader should speak*	The research showed the importance of leadership in collaborative learning in RALs being able to take into account students' dialogue and behaviour. It showed that there were many responsibilities involved to facilitate effective dialogue and individualised learning and evaluation simultaneously, including the management of procedures and time. This also required an adequate knowledge base in order to advise and clarify key concepts as well as circulating data support to team members and being sensitive to different language and cultural backgrounds. Much depended on the skills of the leader combined with the design and structuring of the learning activities to make the collaboration occur and support participants who may need assistance. The participants identified necessary leadership characteristics, including patience easygoingness, ability to deal with team members, having good time management, communication, social/interpersonal/soft skills to deal with student diversity, besides having a respectful manner, strong theoretical background and experience for the topic.

The 3 new Principles	Summary of how the principle was intended to apply in the study	How the students’ responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
	dialogue in his leadership role and management responsibilities, illuminating the data as necessary to make the collaboration more successful.	*to clarify and help people understand the issue. The skill of dealing with people with different culture and background makes it preferable for the leader to have this ability. (R05).*	Moreover, the leader was seen as needing the ability to analyse the questions and progress, and proceedings, and circulate the relevant information.
2. Design the application of technology to create a feeling of authenticity.	Voltage Divider Experiment was selected as the simulation activity was synonymous with its usage in real life and it lent itself to problem-based learning. The task and learning activity were designed to address the teaching goals relevant to its application in the real world of working as an engineer. Thus, when the learning activity is related to the context of the work of a student’s anticipated profession e.g. engineering LAB work, in this case, this use of authentic methods, practices and collaborative collegiality, the learning experience should be more relevant and highly valued compared with ‘going it alone’ in a traditional LAB setting. By being able to use technology to communicate with the real world, in a shared laboratory via the Internet, and collaborate within a group in a RAL from different places the research was able to provide examples of effective collaborative dialogue and discussion about the task and learning using technology.	*Students should be prepared to implement technology as a tool for communications. Also, the use of technology creates authenticity, which facilitates the process of collaboration in RALs; social interaction can also facilitate the technology. (O010).* *The video audio communications (technology) gave the activity a sense of reality. A human can be transferring the information throughout their senses if the reason additionally participates in further participate in the work will be correctly done furthermore, because each human has the power for one of these senses. (S09).* *I like the idea very much because I felt it was real and everything I have done; I have seen it with other team members on life without any delay, and we did not imagine this technology and that it would feel like the authentic experience. (Y08).*	The research showed that participants’ collaboration on the Voltage Divider learning activities was proven to be experienced by the participants as real and authentic, although their collaboration was in a RALs online and accessed from different places. Regardless, the research found the learning experience facilitated effective collaborative dialogue about the learning using the technology for LAB work in RALs. It was shown that the need for authenticity should be applied from the start when planning and designing collaborative LAB work in RALs. In addition to engaging in cooperation, it was also seen to facilitate the connection of the real-life context with members of the group through highlighting their mutual interests. Findings suggested that building in realism may be of particular importance to student learning because their initial beliefs about the validity and reliability of the technology as well as the online collaborative learning pedagogy may play a more important role in influencing perceptions of the

The 3 new Principles	Summary of how the principle was intended to apply in the study	How the students' responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
	Also, the availability of technology access and speed were highlighted as the vital and primary factors in enabling the RALs experience in the first place. Secondly, the equipment for both the task and the video conferencing also underpinned the facilitation of the experience. Thirdly, the task and learning activities design needed to acknowledge the need for appropriate standards of quality and internet speed.		effectiveness of LAB work delivered this way. Thus, the research raised the importance of considering this and the need to merge visual representations, in adding presence and making the RALs LAB learning experiences as realistic and meaningful as possible.
3. Prepare students to be aware of and use soft skills in their collaborative dialogue. .	The activity was designed with the roles and responsibilities of the participants in mind in the context of a collaborative approach to learning. It aimed to acknowledge the contrast between this social constructivist approach compared to a more traditional approach of in-LAB work. In doing so the design of the task and the learning activities took account of the this 'switch' to a collaborative approach and how it needed to lead and facilitate communicative interactions between the participants, thus drawing upon the selected underpinning theories for collaborative learning. The focus on the collaborative approach was selected because it can involve students in learning and practising skills not available in	*The task saves time and corrects any information that could be wrong. But the members of this work could improve their communication skills and dialogue skills to help participants to be more comfortable in speaking about the information. (O010).* *Honestly, I have excellent experience in laboratory work, but these skills have added excellent new information to help me fulfil the activity procedures, and it was a significant thing to be part of this experience. (S09).* *The variety of experience and theoretical skills will build the group with teamwork skills and make the leader's duty easier, and each member will contribute with their substantial experience*	The research has shown that in facilitating positive participation the task and learning activities design need to ensure the account is taken of the fact that to learn effectively through collaboration relies upon the so-called 'soft skills' in addition to students' prior knowledge and discipline and this case technology skills. These skills included skills such as teamwork skills, communication skills, interpersonal skills, problem-solving and critical thinking skills, as these skills were shown to be necessary to support positive collaborative dialogue. Ensuring awareness of these skills for both the leader and participants is necessary to ensure constructive conversations and respectful acknowledgment of individual differences in speed of learning and also provide encouragement. This

The 3 new Principles	Summary of how the principle was intended to apply in the study	How the students' responses confirmed the principle applied to their RALs experience	Relevance to the research into collaborative learning in RALs
	traditional LAB work that are also relevant to students' future employability that will typically involve working in teams and joint problem-solving. During the activity, participants needed to work with each other, and listen to their opinion while waiting their turn to answer and question or comment. The design of the task and the leader's and participants' roles and responsibilities were based on facilitating equal participation and simultaneous interaction and enabling participants to learn effectively and ultimately individually master the task.	*to help other members gain advantages from others' skills. (O010).* *Working with this system anywhere, anytime and within a group increases the team members' skills giving more training. It may improve the engineering activity materials and help put this in the course to help students' meet their needs to make them understand the challenges that may occur in their future work. (S09).*	appeared as important to learning so needs to be central to encouraging active participation in the context of social learning. A member of a group needs adequate time to reach their learning goal, which can depend on the formulation of a trusting relationship with team members that rely on their acquisition of these soft skills. Members need to work as a team in continuous time yet take individual accountability for their contribution and learning. Thus, in any plans to adopt the collaborative approach to learning needs to consider the extent to which such soft skills need to be taught and how much the success of the experience can rely on students' learning during the RALs collaborative LAB work. However, the adoption of the collaborative approach to learning can also be argued as a key component of their course or program in preparing engineering students for work in the real world.

6.3.4.2 Design the application of technology to create a feeling of authenticity

Although the reliance upon technology-based communication in this research trial of LAB work in RALs was clearly evident to all in its use of Zoom CLOUD technology as a video conferencing tool, it cannot be denied that it was the principal critical factor that underpinned the ability to offer learning remotely and synchronously. Since it enabled the participants to collaborate through the use of the video and audio technology, their ability to learn successfully depended on the learning and pedagogical approach being adaptable to the online learning environment. Thus, the research findings illuminated the importance that should be given to the learning task design and facilitator protocols necessary for students' collaborative learning success in the changed learning environment. The issue of ensuring that students gain a feeling or sense of reality was central to their feedback. It was pleasing to find that the participants reported that the Voltage Divider Experiment did meet their expectations regarding technology conveying a sense of realism. The activity was based on connecting several RALs in different places and was able to demonstrate effective dialogue and debate about the learning using the technology. The participants reported their experience to be authentic in terms of their opportunity to learn through collaboration. However, as technology availability is one of the essential factors in aiding collaboration in RALs through Internet access and there is a need for appropriate standards of quality and Internet speed, it is essential that this principle be applied when planning and designing for LAB work in RALs.

6.3.4.3 Prepare students to be aware of and use the soft skills in their collaborative dialogue

The need to prepare students to be aware of and use the soft skills in collaborative learning emerged as a new principle as a result of both the observations of the video sessions' dialogue and the feedback from the participants during their interviews about their experience in learning collaboratively. While the collaborative approach was shown to benefit the entire group as they naturally cooperated and dialogued with the leader and between each other to complete the task, it also showed that to maximise the quality of their engagement it required participants to have effective interpersonal skills and soft skills, including intercultural sensitivity. Moreover, in keeping with Hughes, Bradford, and Likens (2018) and Jerome and Antony (2018), this finding reinforces how higher education learning such as this needs to relate to students' future employability skill needs—not withstanding that they are likely to be working in multicultural settings. Such skills are necessary to ensure careful listening, mutual respect between team members, and respect for each other's viewpoints, and are helpful in supporting joint problem-solving. As it also relates to being able to deal with issues and questions that may arise, and differences in participants' grasp of the concepts involved, the roles and responsibilities of both the leader and team members need to be understood, as do the skills that underpin communicating collaboratively. This aspect of the research highlights the contrast between learning collaboratively in RALs compared with the absence of the opportunity for learning and practising these skills in the more monologic traditional in-LAB work,

6.3.5 Collaboration in RALs instructional framework

Since the research aimed to develop an instructional framework to inform future research and implementation of the collaborative approach in RALs, based on the results of the study, this framework is presented in Figure 6.4. It is designed for use by those who are involved in the design of LAB work to be provided through RALs and intend to adopt a collaborative approach to learning based on social constructivist learning theory. This takes into account that the research findings support the application of Kagan's PIES, Dillenbourg's elements and the Doolittle eleven principles of learning experience design; plus, the three additional principles that emerged from the research. This can be used in the future by others who are planning to develop collaboration in-LAB work online in RALs. The framework directly applies to academics and instructional designers involved in teaching engineering students with regard to LAB work where implementation in RALs may be necessary because of distance and resourcing considerations. However, it is also argued on the basis of this research that it can be a legitimate choice because of the added benefits. Figure 6.4 highlights the sequential nature of planning and delivery based on sound pedagogical theory and draws attention to the need for creating an authentic learning experience. It points out the essential requirements for all participants to have access to the Internet with appropriate speed, together with effective video-conferencing and experimental equipment, such as the Voltage Divider Experiment in this case. Besides outlining the need to consider the underpinning principles and pre-requisites, in terms of the preparation of students' technological, soft and interpersonal skills, it identifies task and learning design principles, the elements of collaborative learning and the key outcomes (theoretical bases). By drawing attention to the pedagogy of collaborative learning, it shows how planning needs to address, in detail, the task design protocols, and roles and responsibilities, including the leader's preparation, guide and task sheet, and both formative and summative assessment, to enable and facilitate collaborative dialogue.

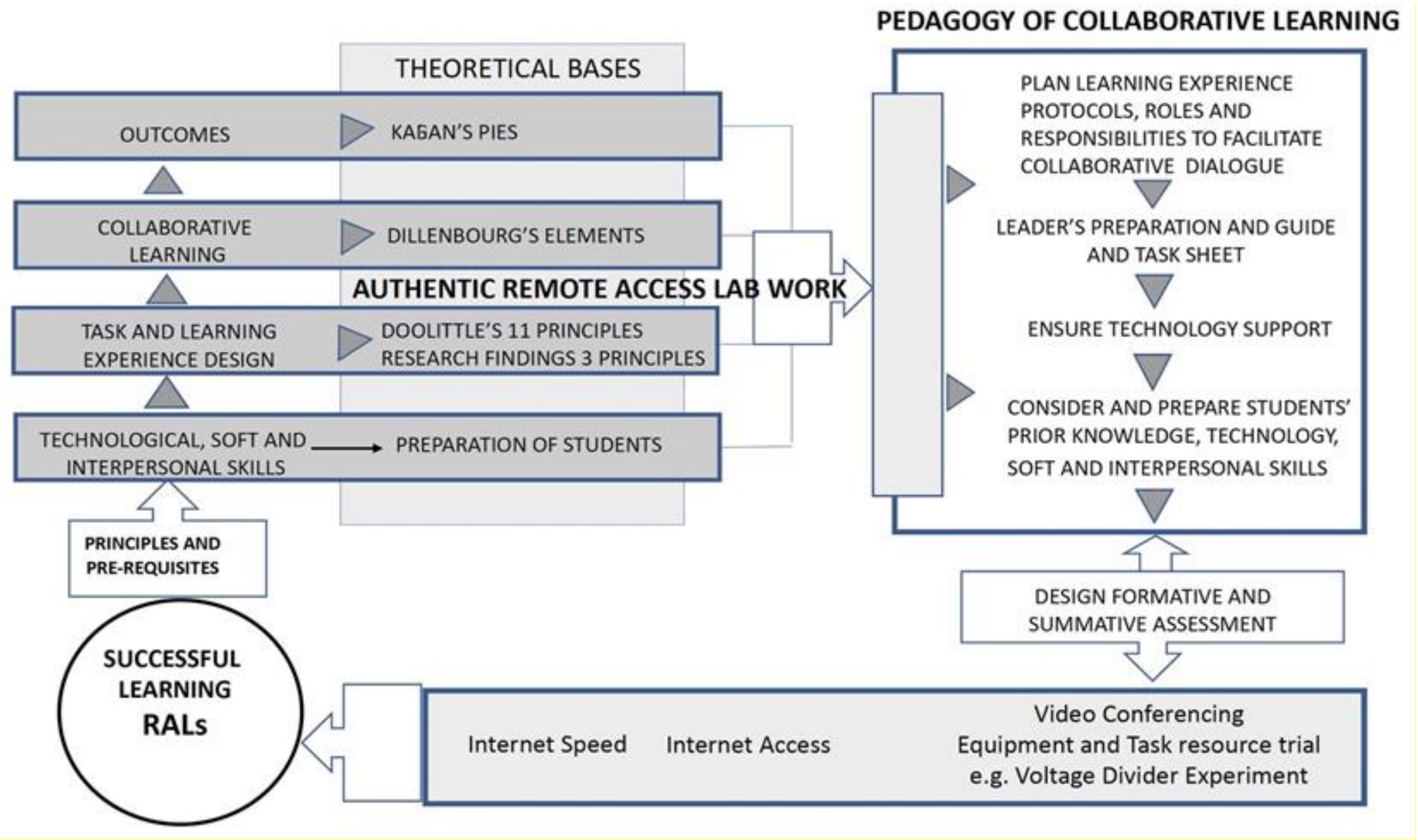


Figure 6.4: The proposed instructional framework for collaboration in RALs resulting from the study

6.4 Summary

This chapter discussed the results of the research, which examined students' views about doing LAB work using the collaborative approach to learning in RALs. Considering the findings from the study, it focused on the relevance of the three theories that underpinned the learning design and the applications of the collaborative approach to enable their collaboration in RALs. It considered the research findings' provision of answers to the research questions, and in doing so explored the emerging findings through mind mapping and the conceptualisation of major themes and issues in terms of a pedagogical model. It also provided an overview of the application of the study's theory base for enabling collaboration and collaborative learning and, as planned, proposed an instructional framework for collaboration in RALs.

As well as outlining the benefits of the adoption of the collaborative approach in RALs it considered the challenges and inhibitors that were seen as influencing its uptake. It highlighted the participants' positive response to the substantial pedagogical change in moving from the traditional individualised in-LAB work to the RALs collaborative learning experience. Thus, the research findings supported the feasibility of this shift in pedagogy through the participants identification both enablers and inhibitors, as well as a range of benefits and suggestions for. Nevertheless, the participants generally were of the opinion that the opportunity to dialogue was more informative for their learning than being isolated working alone in the traditional in-LAB learning environment. For instance, they viewed the collaborative approach and learning via RALs as being able to save time and be more effective for their learning. The role of the leader as facilitator was constructive and in turn, was seen as resulting in a stronger and better quality outcome than in traditional practice as well as reducing participants' stress because of the availability of information and support. Further, working as a team was seen as allowing participants to voice their different points of view safely and respectfully, while broadening their critical thinking by being exposed to different methods to solve the same problem. In culminating with the development of an instructional framework for collaboration in RALs, the chapter advocates for, and provides justification for pedagogical change in the teaching of LAB work in engineering, where the tasks can be provided through the use of technology; in this way and collaborative discussion can take place.

The next chapter, Chapter 7, provides conclusions and recommendations of the research. It provides a summary of the answers to the research questions and discusses the implications of the research for practice and its contribution to knowledge, taking into account the research limitations. This is followed by a discussion of the study's implications for future research into the collaborative approach in RALs learning in higher education and outlines the conclusions to the study.

Chapter 7 CONCLUSIONS

7.1 Introduction

The aim of this research was to explore the potential use of Remote Access Laboratories (RALs) in higher education undergraduate engineering courses to provide a more contemporary pedagogical approach to learning—as opposed to the traditional, physical, in-LAB learning experience. This involved the implementation of a collaborative approach to learning that depended on the use of technology and Internet access. A RAL collaborative learning task was designed that focused on the Voltage Divider Experiment, where participants were encouraged and guided to collaborate, taking into account the theoretical bases of Kagan's PIES (outcomes of collaborative learning), Dillenbourg's four elements of collaboration, and Doolittle's eleven principles of learning experience design. An instructional guide for the facilitation of student collaboration was also developed and trialled, taking into account these theoretical bases. This element of the study also allowed the development of a theoretical framework for fostering collaboration as a potential future tool for application in the uptake of learning through RALs.

The overarching research question focused on the extent to which engineering students accepted the collaborative approach to learning in-LAB work that is implemented in a non-traditional way, through remote access laboratories. The extent to which this was accepted as a workable alternative to traditional lab work was the focus of the research. It also sought to determine the factors likely to influence its adoption, including factors that need to be considered when planning to implement collaboration in RALs, and the challenges and issues that may inhibit such uptake. The research also aimed to determine the benefits of adopting a collaborative approach to LAB work learning through RALs and its potential impact for future learning. More specifically, it investigated what a shift to a collaborative learning approach in RALs requires in practice. This included an investigation of how to best support students to collaborate in the RAL learning environment. Section 7.2 provides a summary of the research findings in relation to each research question. Section 7.3 addresses the research contribution to knowledge in terms of both theory and practice; and Section 7.4 provides recommendations for future research.

7.2 Summary of the Research Findings in Relation to the Research Questions

This section provides a summary to each question in this research, outlining the key findings. Each of the questions is addressed in turn.

RQ1 To what extent is collaborative learning in RALs accepted by engineering students as a workable alternative to traditional LAB work?

This question explored collaborative learning in RALs from the students' perspective. The study established students' acceptance of collaborative learning in RALs. This was supported by the results from their activity reporting task, observation of the RALs learning experiences and analysis of students interviews which helped determine the level of collaboration in the RAL activity, the processes were required to undertake it and students' views of the collaborative learning experience. Thus, this finding relied upon the discussion and reporting on the activity, consideration of the comments from students related to the various steps in the activity, RAL collaborative experience observations and analysis of the participants' behaviour while learning in RALs. As well, this finding was strengthened by the triangulation of these data gathered via post-learning experience interviews with the participants. As a result of these analyses, the findings show that the participants had a very positive attitude toward collaborative learning in RALs and demonstrated an acceptance of it working effectively for learning Lab work in RALs. Moreover, these findings relate very well to the theoretical bases of the research in terms of Kagan's PIES outcomes of collaborative learning: positive interdependence; individual accountability; equal participation; and simultaneous interaction. Students who participated in the study reported that the effectiveness of collaboration in RALs did indeed meet the outcomes considered by Kagan's PIES. Individual accountability resulted in everyone in the group seeing themselves being responsible for their own learning thus refuting a common perception of 'group work' learning being unfair in terms of individual assessment. Equal participation by the students was seen as having an equal value within the group's experience. However, this aspect is not easy to implement unless the roles are changed regularly to allow all students to attempt specific roles. By ensuring simultaneous interaction, all students were able to participate actively in the task at the same time and not be inhibited by some less knowledgeable peers. The study found, based on Kagan PIES, that collaboration had accrued, and the students confirmed this by indicating that all basic issues were covered in the remote laboratory activity. Considering of Kagan's PIES in the design stage resulted in an environment where students worked together, gained social skills, cared about each other's learning, and achieved success. It can provide a more consistent and successful learning experience in the collaborative process. Students worked in teams to discuss issues and solve problems together. Each member was expected to contribute and was structured into the activities. They were all regularly held accountable to their peers for their individual contributions. Also, students felt their experience in the RAL learning environment supported a path to fruitful collaboration, where they were involved in experimenting together with the Voltage Divider task. Importantly, their involvement in activities gave them opportunities to develop other positive outcomes such as team members being able to work effectively together and support each other (teamwork skills) to ensure they completed the task and achieved successful outcomes with a sense of reality. The participants exhibited a deep understanding of their collaborative learning experience in RALs and saw it as an overall acceptable approach in engineering Lab work. The results of this aspect of the research was essential to verify students' acceptance of collaborative learning in engineering in RALs or not, and therefore showed it was seen as an effective alternative to traditional Lab work. The participants conveyed the view that the activity was real to them, despite it being achieved through the use of online technology. They were of the view that its originality made it feel like a traditional Lab, and that the use of video and voice, and the communicative purpose delivered a sense of reality. Moreover, the students perceived it as an authentic learning experience.

RQ2 What are the actual factors that need to be considered when adopting a collaborative approach to learning in RALs?

The answer to this question was derived from observation and analysis of the participants' behavior while learning in RALs; and also through triangulation with the data gathered through post-learning experience interviews with them. As a result of these analyses, which used NVivo, seventeen key factors were derived, that were seen as enabling students’ collaboration and interaction with each other during the RALs learning experience. These factors are considered highly significant for collaboration in the implementation of RALs and involve recognition of leadership, preparation, student level, technology, familiarity of a topic, relationship, student's task, culture and background, time, questions, experience, languages, trust, difficulty and undefined information, interesting topic, fun environment, and incentive. Furthermore, six inhibiting factors were also identified that the innovation depended upon and/or needed to be particularly considered to improve when embarking on learning in RALs. These were technology, time, languages, unfamiliarity with the topic; leadership, and relationships. Based on interviews, student task reports, participation, observation and activity recording, the findings showed that the participants had a very positive attitude toward collaborative learning in RALs and provided new data regarding the factors that facilitate collaboration and the issues needed for improvement in the future. These findings relate very well to the theoretical bases of the research in terms of Kagan’s PIES, as well as Dillenbourg’s elements of collaborative learning (context, interactions, processes, and impacts), and, likewise, Doolittle’s eleven principles of learning experience design. However, it was also found that additional principles applied for collaborative learning in the RALs environment in contemporary times in terms of students requiring preparatory skills for collaboration. The research revealed the importance of the ‘soft skills’ in collaborating with peers, and the skills needed to support working with the experimental task, and their differing roles (e.g. leadership and participant). Thus, the results of this aspect of the study highlighted students' perceptions of the needs of their role and that of the learning context during their collaboration in RALs, and the importance of the authenticity of the collaborative learning experience, which was dependent on the Internet and information communication technology. Yet, the participants showed a deep understanding of their collaborative learning experience in RALs and saw it as an overall acceptable approach in engineering LAB work, that had significant advantages over the traditional approach. Thus, the enabling and inhibiting factors are further summarised below.

The enabling and inhibiting factors that need to be considered when planning to adopt collaboration in RALs

The research participants pointed out the need for leadership and preparation for the learning task collaborative process, also noting the importance for students to be generally at a similar level of prior knowledge and skills to enable effective collaborative learning. These findings also highlight that achieving this requires lecturers/academics to have not only sufficient knowledge to design learning task and experiences but also to be aware of the prerequisite skills required by students and their zone of proximal development at the time of learning. This is necessary to ensure collaborative learning can be successful in terms of students being able to contribute constructively. Thus, participants demonstrated they were able to critically discuss and identify problems, including the need for some familiarity with the topic, task content and relationships, and awareness of time, as well as the cultural and language background of their peers. The handling of questions, however, was raised as an important issue with regards to needing improvement, since it was found that although an interesting topic, at times the discussion was difficult because of undefined information. They advised the need to build in a fun approach to learning in RALs, and also recognised advantages to the environment and higher education financial savings as incentives in adopting collaborative learning in RALs.

While there have been some recent developments that have increased the prominence of the availability of technology to support the adoption of a collaborative learning approach in RALs, it is dependent on the efficiency of the Internet and the availability of high-quality simulated tasks and equipment. Nevertheless, this trial of the Voltage Divider Experiment demonstrates the possibilities and, in identifying both enablers and inhibiters, it can be deduced that it is an attractive approach that offers many advantages to both lecturers/academics and students. Thus, the findings of this research are expected to assist institutions and RAL providers in evaluating the possible adoption of a collaborative approach to learning in this way, and increase their awareness about strengths, challenges and issues that may influence its adoption and improving approaches to teaching and learning. The results of this section of the research were essential to gaining an improved understanding of the factors that impact collaborative learning in RALs, and how these may be used to advantage and supported by improved and informed managerial level decision-making processes as necessary for institutions and RAL users.

RQ2.1 What does a shift to a collaborative learning approach in RALs require in practice?

In response to this question the research trialled the implementation of the collaborative approach to learning in the RALs environment with particular relevance to Lab work in engineering. In demonstrating the possibilities through the testing of the application of the three theoretical bases that related to the learning experience design, elements of collaboration and the projected outcomes of learning, an instructional framework (see Figure 6.4) was developed as an outcome of the research, which is highly pertinent to this research question in guiding future teaching and research in RALs. This instructional framework for collaboration in RALs resulting from the study demonstrates the requisite successive nature of planning and delivery based on sound educational theory. It acts as an educational guide to facilitate cooperation and the collaborative learning experience in RALs, though remains relevant to those intent of using the collaborative approach to learning in general e.g. without the mediation of technology.

As well as drawing attention to the need to create an authentic educational experience, i highlights the basic requirement for participants to have Internet access to be able to experience collaboration in RALs and collaborate online; along with appropriate technology, quality of Internet speed and effective video conferencing and experimental equipment. These elements are essential requirements in preparing students' technological skills, and the communicative skills, including soft skills to be able to work effectively with others, not withstanding consideration of adequate background knowledge. They are also important principles in the design of learning, elements of collaborative learning and key outcomes (theoretical foundations) to consider. Through the focus on cooperation in this learning space and the collaborative, problem solving pedagogical approach to learning, it shows the extent and fruition of the detailed planning of task design protocols, participants' roles and responsibilities to facilitate collaborative dialogue, including preparation, guidance from the task sheet leader, and both formative and summative assessments.

The RAL collaborative learning task focused on the experience of shared efforts, which encouraged participants' directed cooperation, and was designed taking into account the theoretical underpinnings of Kagan PIES cooperative learning outcomes, four of Dillenbourg's elements of cooperation, and Doolittle's ten principles of learning design experience. Thus, the research also reinforced the relevance of applying these theoretical bases as legitimate in providing the foundations of collaborative educational design for the learning experience of a RAL. While confirming their continued importance in this context, three new principles also emerged from the research as necessary to facilitate and enhance contemporary learning in RALs. These were (1) to ensure the role and responsibilities of the leader and participants are sufficiently structured in terms of achieving the learning objectives of the task to facilitate positive leadership and enable effective collaboration in the RALs, (2) to design the application of technology to create a feeling of authenticity, and (3) to prepare students to be aware of and use soft skills in their collaborative dialogue. These are vital to building-in and facilitation of the collaborative learning experience. They bring to the fore the need to consider important workplace issues and ensure participants acquire the requisite skills, including interpersonal and teamwork skills (soft skills), which are also relevant to their future careers. These three new principles also highlighted the need to define the roles and responsibilities of the leader and participants to best enable effective collaboration; to design and apply technology to create a sense of originality, and to ensure students are prepared in terms of their skills to effectively collaborate.

The research also revealed how the uptake of a collaborative approach fostered dialogic learning in the RALs learning environment, and how this takes the learning beyond the traditional monologic experience of an in-LAB approach to one which more closely replicates the demands of the actual workplace. However, it is extremely important in facilitating learning that the experiences are not too difficult for students, as this would hinder their learning and likely impact their motivation. Thus, those intending to replicate or apply the collaborative learning approach in RALs should ensure the task is designed with a comprehensive awareness of the knowledge and skills of the students, so that they can build on their existing knowledge in preparation for the development of new applications, besides acquire the new knowledge and skills needed to master the new tasks.

The importance of preparing the introduction by the leader and establishing the appropriateness of learning activities is vital; and support can initially be offered and then gradually withdrawn in the context of collaborative learning in keeping with Doolittle (1992). Participants noted that the applicable preparation in all stages, including trial, training, and formation of reference materials, was necessary to facilitate experimentation and learning with the sharing of effort. One factor that the team identified was the need to train more than once before the learning experience to reduce gaps in knowledge between different team members and in turn make sure the learning episode ran smoothly.

Since the essence of collaboration is based on information exchange and shared problem-solving where the design of a group leader's mission to facilitate dialogue includes wise interrogation to build logical arguments, the collaborative approach was also seen to improve learning through critical thinking, thereby encouraging participants to think about the task. The participants concluded that supporting documentation for evidence was the most vital role of the leader to influence overall learning success, given that a task was appropriately designed for their learning. The need to ensure the structure of the task and roles was supported by the role of the leader, along with familiarity with the topic. Students also felt that the effectiveness of a leader in guiding the mission helped them to achieve results in a shorter timeframe than if they were working alone. These benefits made the activity simple, reduced task difficulty, led to more questioning discussion and understanding of the activity and enhanced collaboration with their colleagues. Their task included both addressing and discussing important issues and interpreting data to demonstrate their understanding of the fulfilment of the evaluation.

In addition, the approach included formative assessment that naturally occurred throughout the task by nature of the collaborative activities and protocols where the leader monitored progress and gave continuous feedback. Students were therefore evaluated on an ongoing basis using authentic and informal methods that promote the belief that engaging students in teamwork is fun, rather than evaluating them based on traditional exams and tests. In the process, students also learnt from each other through their communicative interactions and the support they receive from the leaders and their peers. Students also reported they made their own efforts to elicit and build on more information, which accrued by asking each team member's opinion or reviewing new ideas different from the central concept, all of which contributed to successful teamwork and individual work.

RQ3 What are the actual significant benefits to students in adopting a collaborative approach in RALs?

This was an important question to consider with regards to gauging the impact of the adoption of new technology and engaging students in the pedagogical change required both through the use of RALs via the Internet and learning collaboratively. The identification of the benefits that could be described as significant stemmed from the participants' reporting on their experience in the study's implementation of collaborative learning in RALs, and through the observation of their experience. The findings indicate that the use of the RAL learning environment and the collaborative approach was able to foster pedagogy and learning that is a feasible alternative to traditional in-LAB work. Moreover, it was found to have the potential to add value to students' learning in their acquisition of skills more in keeping with their future workplace needs (including soft skills such as teamwork and interpersonal skills) compared with the more monologic traditional approach, where there is little or no interaction between participants. This adds value to the learning experience as it is highly relevant to ensuring engineering students have the soft skills to be able to work with others collaboratively, but also be sensitive enough to be able to show leadership and negotiate with regards to problem-solving in their field. Further to this, participants identified how, through the collaborative approach to learning, their experience allowed them to better develop their understanding. Related to this was the ability of the collaborative approach to facilitate formative assessment, where the structuring of the learning experience and the design of the stimulus questions can assist in the co-construction of new knowledge. Learning is additionally supported in this approach through the recording of RAL sessions for students to revisit at a later date. By providing such a potential follow-up session, whether accessed individually or in pairs or a small group, learning can be reinforced.

In addition, where in-LAB work can be conducted remotely via RALs using a collaborative approach, it can result in saving of time and financial resources for students (as well as providers). The participants were of the opinion that the ease of accessibility and the availability of the RALs' sessions for learning, as well as follow-up resources, improved the quality of service delivery. They also noted that the collaborative approach provided a supportive learning environment, where members of the team assisted each other when dialogue that transpired indicated a need for assistance. *The ability of the approach to reduce the level of risk was also identified as a significant benefit, because simulated online activities provide a safe learning environment.* Since the core of collaboration is based on sharing information and joint problem solving, where the task design incorporates a group leader to facilitate the dialogue through judicious questioning to construct logical arguments, the collaborative approach was also viewed as improving learning through fostering participants' critical thinking about the task.

7.3 The Research Contribution to Knowledge

This research investigated the feasibility of teaching LAB work, a core learning component of engineering undergraduate degree programs, through RALs, using a collaborative approach to learning. This contrasts with the traditional model, where students typically work alone in a LAB to demonstrate their compliance with a procedure in the absence of any stimulus for creating discussion. The findings contribute to knowledge in both a theoretical and a practical sense. The core contributions are:

- Development of an instructional framework to guide future practice.
- Discovery of three new principles to facilitate and enhance contemporary learning in RALs.
- Practical contributions.

Each are described below.

7.3.1 Development of an instructional framework to guide future practice

The main contribution of this research is the establishment of an instructional framework with recommendations for its use to facilitate effective online collaboration in RALs in the field of undergraduate engineering programs. This was developed through a case study on the efficacy of the collaborative approach for teaching LAB work in engineering in the context of RALs in the light of the Doolittle principles for collaborative learning and Kagan's PIES; in conjunction with students' views on their RALs experience and the pedagogical change. In addition, the resultant instructional framework is also relevant to implementing collaborative learning online generally, thus contributing to a deeper understanding of the implementation of social constructivist pedagogy in higher education. Besides adding value to existing understandings and challenges of the traditional pedagogy of LAB work, the findings provide insights into how student collaboration in RALs stimulates critical dialogue to enhance learning outcomes compared with the traditional monologue. Thus, it provides strong evidence for online collaboration in RALs being central to future online teaching of electrical engineering students in virtual learning environments. Thus, it both confirms and goes beyond the findings of Gadzhanov and Nafalski (2010); Hwang, Kongcharoen, and Ghinea (2014) and Admiraal et al. (2019) by not only showing that student collaboration in RALs can play a crucial role in positively influencing their learning outcomes and perceptions, but also demonstrates how collaboration occurs and provides a contemporary framework for future action on pedagogical change in Lab work

The study focused on the implementation of collaborative learning. The theoretical bases of Kagan's PIES that relate to outcomes of the collaborative approach, Dillenbourg's four elements of collaborative learning and Doolittle's eleven principles of learning experience design were applied to the research task design and design of pedagogical protocols such as the instructional guide. Similarly, the fact that the collaborative approach to learning, which although not new, remains a paradigm shift for those involved in teaching and learning traditionally through transmission of information view of learning, was trialled in the context of RALs adds an additional dimension to both theory and practice. The research also allowed the development of an instructional framework to guide future practice. Finally, the research gives voice to students with respect to both their learning in Lab work online in RALs and the change in pedagogical approach.

7.3.2 Discover three new principles to facilitate and enhance contemporary learning in RALs.

In the context of exploring this pedagogical change and the opportunity for the teaching of LAB work in RALs applicable to engineering, the research demonstrated how the use of technology and access to the Internet could effectively facilitate this alternative to in-LAB work. It showed that for the case of the Voltage Divider Experiment participants could effectively explore the task and interact with their peers from their different locations. However, while it also showed the success of the collaborative approach in being able to take account of the participants' varied starting points, the task and collaborative learning experience design was able to ensure that no participant was left behind. It also provided support for the applicability of the theoretical bases that underpinned the task and collaborative learning experience design. In particular, it was found that Doolittle's eleven principles all applied to the design of the online learning experience, which emphasise the importance of ensuring account is taken of students' ZPD, besides the vital importance of task authenticity, which was evident both in focus on the Voltage Divider Experiment learning activities and the design of the instructional guide to stimulate the collaborative discussion. Nevertheless, the research also concluded that in this contemporary learning context of RALs and collaborative learning that draws upon a social constructivist view of learning as the co-construction of new knowledge, three additional principles apply. These are (1) ensure the role and responsibilities of the leader and participants are sufficiently structured in terms of achieving the learning objectives of the task to facilitate positive leadership and enable effective collaboration in the RALs; (2) design the application of technology to create a feeling of authenticity; and (3) prepare students to be aware of and use soft skills in their collaborative dialogue. These principles highlight the added challenge to design authentic learning experiences for delivery online where equipment and tasks are usually only available in the physical space of a LAB. They illuminate the importance of shifting to a collaborative approach to learning in illustrating the need to structure the learning experience in terms of fostering dialogue, building in formative assessment practices and ensuring students have acquired the requisite soft skills to effectively collaborate. In doing so, they indicate the need for change in traditional assessment practices to provide data that is formative and that is able to feed forward in engaging and enabling students' learning.

These three new principles therefore draw attention to designing LAB learning experiences for delivery in RALs and also in the context of a collaborative approach to learning. As well, these principles are relevant to designing collaborative learning experiences in general, having relevance to collaborative learning applied to other disciplines. The research findings also led to the development of an instructional framework to inform future research and implementation of the collaborative approach in RALs. Its use is applicable to those who are planning to adopt a collaborative approach to learning based on social constructivist learning theory in particular. This framework outlines the major needs of participants with regards to efficient Internet access and appropriate video-conferencing software. As well as noting preparatory needs, including principles of pedagogy and students' technological, soft and interpersonal skills, it alerts the user to developing task and learning design principles, the elements of collaborative learning and the planned key outcomes. In highlighting collaborative learning as a model of teaching it guides the user to consider the task design protocols and roles and responsibilities, the leader's preparation, guide and task sheet, and both formative and summative assessment, to enable and enhance learning success.

7.3.3 Implications of the research

The deliverables of this research aimed to contribute not only to future remote access laboratory teaching and learning, and research, but also to foster improvements in higher education institutions' services, particularly engineering education. The findings offer support for such institutions to use the collaborative approach to learn more effectively and efficiently, and particularly in RALs, by identifying the major influences involved. These include both enabling and inhibiting factors. A detailed discussion is carried out below about the implications of this research and its applicability to various groups and disciplines, as well as higher education providers. As revealed by the research, soft skills emerged as being necessary for successful collaboration; and as these skills are also key to workplaces where staff need to collaborate, the approach and instructional design in this research provide an exemplar and rationale.

Higher education institutions can be considered as potential RAL service providers, which represent a vital part of the market and the economy of the country by providing various essential educational services both domestically and internationally. Thus, higher education institutions play a critical role in the provision of LAB work in their implementation of engineering programs and they require research such as this to help inform their practice. As noted earlier, a shift, where feasible, to LAB work via RALs is a strategic decision that can enhance services to students off-campus and also contribute to budget savings, while adding value to students' learning experience by enhancing their preparation for work in terms of their soft skills and IT skills. In addition, these research findings draw attention to the design and use of strategies for the broad adoption of collaboration, where a technology trainer may assist and, therefore, needs to have an understanding of the context. Specifically, those involved in pedagogical redesign in the adoption of the collaborative learning approach in RALs can gain a deeper understanding of students' learning needs and how collaborative learning and teaching can be made explicit in the tertiary pedagogical setting regarding LAB work in RALs.

However, the decision to move to a social constructivist approach to learning through collaboration and apply this in RALs in engineering education is a decision not without risk as it must be feasible to achieve the LAB learning objective. On the other hand, the conduct of LAB work in the RAL environment where learning is through the use of simulation can be a much safer option when there can be dangerous consequences if equipment is misused. Therefore, the higher education sector needs to be aware of the potential benefits that this use of technologies can bring to engineering students. A better understanding and awareness of the nature of collaborative learning and the

RAL learning environment and anticipated benefits is vital to improving pedagogy and service to students, as well as furthering innovation. However, students in the present research were of the opinion that universities have been slow to adopt the collaborative approach to learning because of a general lack of understanding of the technologies involved. An additional contributing factor is the lack of readiness of academic staff to be able to design tasks and learning activities for RALs and teach collaboratively and, accordingly, design appropriate assessments. Anecdotally, at the completion of this thesis the need for higher education providers to move all courses to online learning because of the coronavirus pandemic is reported to be very difficult because of the lack of staff knowledge and skills, and also infrastructure. Thus, the present research illuminates the possibilities for a shift to LAB work via RALs, but also the advantages of adopting a collaborative approach to learning. Moreover, it provides an instructional framework as a guide to planning and implementation and outlines the anticipated benefits of collaborative learning in RALs. This research provides assistance to those service providers, academics and technology specialists in higher education who are contemplating its uptake; and is helpful in paving the way for pedagogical change and enhancement of teaching skills. Although there may be feelings of uncertainty associated with the adoption of collaborative learning, as well as the use of RALs as opposed to traditional in-LAB work, it is important to consider the research and the benefits, and also professional development for staff. Similarly, the research shows that students also need to be considered when changes are made to pedagogical approaches so that they understand the reason for change and the anticipated advantages. The nature of the learning environment in relation to students being ready to engage in the task activities was shown to be a vital consideration; as was their interest and motivation to learn. However, in learning collaboratively the importance of the group dynamics came to the fore in noting the importance of trust and respectful interactions, where students require soft skills, such as interpersonal skills and teamwork, to most effectively collaborate. Participants' collaboration in this research was supported by the learning activities design that involved a leader. This was advantageous in facilitating the collaboration since the task design protocols and roles and responsibilities required the leader's preparation, guidance and task sheet, in addition to the inclusion of both formative and summative assessment to enable and enhance learning success. Thus, the research shows that the adoption of a collaborative learning approach to teaching in RALs is feasible if sufficient planning and preparation occurs, which suggests institutions should be capable of delivering selected LAB work via RALs in a secure and reliable learning environment. To reiterate, the research findings are supportive of this strategy in its capacity to contribute to courses that involve LAB work learning because of 24/7 accessibility and follow-up through recordings, as well as value adding the use of soft skills, and, in turn, providing economic benefits for providers in a convincing way. This leads to a supportive environment for the remote access laboratory.

Additionally, the results of this research can assist higher education providers to improve their awareness of the advantages of the adoption of collaborative learning or using RALs; and also assists in addressing any concerns in relation to adoption. It can also help stimulate the conversation between the providers of collaborative technologies such as video conferencing software (e.g. Zoom that was used here), and higher education institutions or research centres that can benefit from its uptake.

The growth and development of online collaborative learning may also lead to evaluation of institutions and research centres and incentives encouraging the technology adoption in RALs. Through facilitating consideration of the aspects that affect the adoption and implementation of technologies such as online collaboration, this collaborative approach can support connecting the benefits of the technology execution efforts across courses, programs and institutions or other agencies. The research outcomes contribute to a comprehensive understanding of the factors that need to be considered when planning to adopt a collaborative approach to learning in RALs. Anticipated benefits, challenges and issues in the implementation of this model of teaching in RALs have been outlined in this research, the findings of which have the potential to improve teaching and learning in Lab work and encourage increased student accessibility for those tasks that lend themselves to simulation in RALs. It can be assumed that collaborative learning in RALs has the potential to reduce the cost of infrastructure operations for providers and this specific research provides information for a multitude of entities including government, institutions, research centres and higher education—as well as service providers.

7.4 Recommendations for Future Research

As a case study, this research was limited to a small group of engineering students and one particular task in the Voltage Divider Experiment, although the research collaborative learning task and activities design and the RALs learning environment were soundly based on established pedagogical theories. They drew upon Kagan's PIES that relate to outcomes of the collaborative approach, Dillenbourg's four elements of collaborative learning and Doolittle's eleven principles of learning experience design, which facilitated the development of pedagogical protocols and other support material, such as the instructional guide. In addition, this research focused on how the participating engineering students experienced both the change to a collaborative approach to learning LAB work in RALs, as opposed to the traditional in-LAB work that is typically more monologic. By giving voice to engineering students this research is also of particular interest to all involved in higher education courses that involve LAB work and also those who are interested in shifting to a collaborative approach to learning as it provides in-depth and detailed information on the approach and the task. Thus, in the light of this it is recommended that future research replicates the present study, but includes additional tasks with possible expansion to other areas in engineering or other disciplines. There is also a need to investigate in more depth, through a larger study, the nature of the three new principles of learning experience design, particularly the collaborative skills and soft skills required. This would contribute to strengthening the design of the learning activities to support making a connection to work-based integrated learning. Other research could also focus on the professional development needs of academics who anticipate changing to the collaborative approach to learning or teaching in the RALs environment, as this requires a significant shift to accommodate pedagogical change and use of technology.

7.5 Conclusion

The overarching research question focused on enabling collaboration in remote access laboratories. An instructional guide for the facilitation of collaboration in remote laboratories was developed and trialled to address this aspect. This study focuses on the identification of an existing theoretical framework for collaboration and its application in remote laboratories. The study aimed to investigate how to support student collaboration in remote access laboratories. From the literature review, the theoretical framework was identified, along with discussions of application to RALs development as a methodology for trialling the proposed framework. Doolittle's (1995) principles to support collaboration in a face-to-face classroom were also applied in the context of online learning activities. The essential outcomes of this research study involved a theoretical framework development and methodology. The participants accepted the collaborative learning approach in RALs, and the collaborative learning that took place demonstrated that students could discuss issues and ask questions and manipulate the variables in the Voltage Divider Experiment. The research made a significant change in pedagogy from the traditional individualised, practical in-LAB work. Therefore, the research outcomes support what may be described as a paradigm shift in the provision of LAB work through both changes to pedagogy and the online learning environment with simulation. Advantages were identified for students and for higher education providers, including the contribution to learning and remote accessibility regardless of geographic location. There can also be economic benefits for students and institutions in the adoption of RALs. This capability can also be transferable to other disciplines. The researcher has used only one example (the Voltage Divider Experiment), but further research is recommended with other tasks, as mentioned above. Importantly, following the application of the theoretical bases of Kagan's PIES that relate to outcomes of the collaborative approach, Dillenbourg's four elements of collaborative learning and Doolittle's eleven principles of learning experience design to the research task, three new principles emerged as a result of the research. These principles highlight the need to specify roles and responsibilities of the leader and participants to best enable effective collaboration in RALs, to design the application of technology to create a feeling of authenticity, and to ensure students are prepared in terms of their soft skills for effective collaboration. The research concluded with the development of an instructional framework to guide future practice. Although a case study, this research was quite comprehensive in its investigation and builds on previous studies by investigating both pedagogical change in implementing the collaborative approach and also the switch to RALs for the delivery of LAB work in engineering. Most previous studies covered limited concepts of collaboration in RALs and were more limited in terms of the methodological process, thus, were lacking in breadth or depth. Therefore, this thesis aimed to address these gaps through case study.

Bindé (2005) noted how the creation of contemporary knowledge building communities rely on collaborative, social capacity building practices, where “lines of reflection and action for making communication and information serve the transmission of knowledge, a diffusion one would want set fast in time and wide in space” (p. 6)

(in his report to the Organisation for Economic Co-operation and Development [OECD]).

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APPENDICES

Appendix A: Student task sheet

Student Task Sheet

The diagram below shows the layout of the LabVIEW front page as it is set up for your experiments.
The circuit is already connected and the software has been written and you must access it from this link below:
http://10.31.134.40:8000/voltagedivider.html
If the software is not yet connected, the leader of your team must go to the access link:
http://10.31.134.40:8000/voltagedivider.html
Procedure – task sheet instructions
Now, follow the instructions to the **Activities** below in sequence and write your observations in the spaces provided for the 11 tasks. Talk with your colleagues in the group as you are working out the answers and checking with each other to write the correct answers:

1. **Go to webpage http://10.31.134.40:8000/voltagedivider.html**

The circuit has been connected the made-up on LabVIEW as follows:

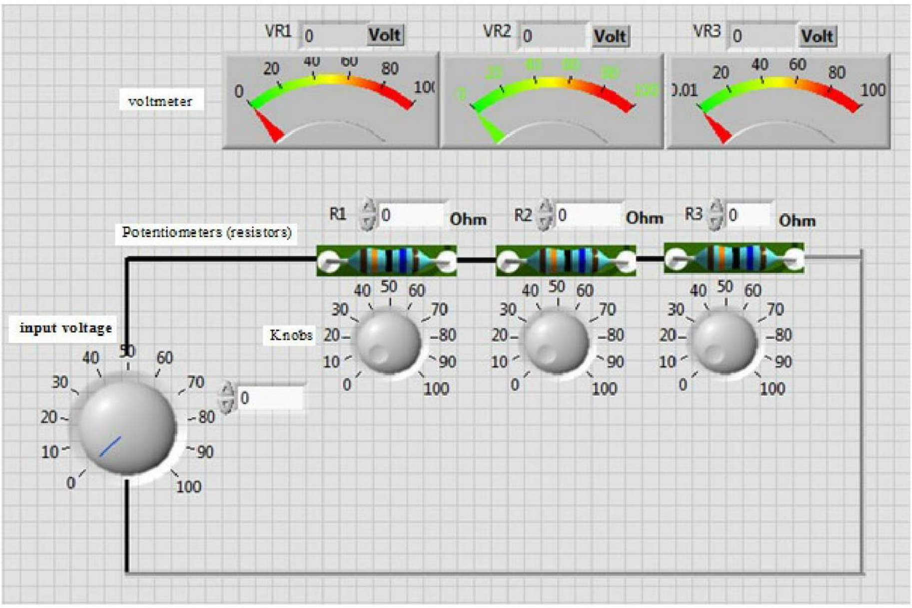

Figure (1) LabVIEW front page

.

- Power with voltages between 0 V and 100 V.

- Potentiometer (resisters R1, R2 and R3) has been connected.
- Monitor the Volt for each resistor with voltameter.
- Ensure that there is a power on voltage in (V in).

2. Apply input voltage of between 0 to 100 volts from the nob to the INPUT and will be monitor on knob and digital number beside the knob as on figure (1). Monitor the OUTPUT with the digital voltmeter which is part of the

3. Check that the voltage divider works correctly by doing the following:

- Ensure that the VR1, VR 2 and VR 3) (voltage crosses resistors) is still operating.
- Adjust the input voltage from the dial as shown on figure 1. You should see the voltage changes according to the input voltage and the value of resistors on the voltameters.
- Now vary the input voltage of the from the dial up and down by hand and observe the following:
  - The voltage cross each resistor ; and
  - The voltage difference between the tree resistors varies from about 0 to maximum voltage on each resistor.
  - In this case there are 3 significant output voltage: VR1, VR2 and VR3.

2. **4. A LabVIEW program has been written and can be accessed from link below (http://10.31.134.40:8000/voltagedivider.html):**
   - Sweep the Potentiometer (resisters) continuously up and down over a range which includes the entire range during which maximum and minimum voltage to each resistor on is achieved.
   - On-screen display of the OUTPUT voltage cross each resistor which should look similar to the calculation result.
   - Use the voltmeter as shone on front panel to measure VR1, VR2 and VR3 and compare them with the theory (calculations method)
   - On remote computer measure the voltage applied across the series of resistors. The front panel figure (1) of LabVIEW will display numerical values for each of the following parameters:
     - The input voltage
     - Resistor 1,2 and 3
     - Voltage cross each resistor VR1, VR2 and VR3
   - Sweep all three alternative resistor through the Knobs.

5. In the event that time is still available, measure and display the VR1 ,VR2 ,VR3, R1,R2and R3:

- Sweep the Potentiometers (resistors) over to get the voltage that cross each resistor.

As the following

R1 ten time R2 R3 equal zero.

R1 the same value R2, R3 equal zero.

R1 Half value R2, R3 double time R2.

6. Does the voltage divider appear to be work at this point? Why?

....
.
....
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....
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....
....
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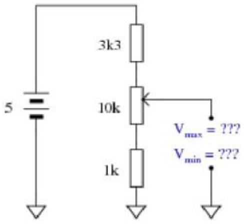
....

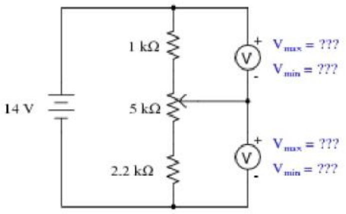
7. R2=3.3k Ω and R3=1k Ω as shown below. Calculate both the maximum and the minimum amount of voltage obtainable from this potentiometer circuit (as measured between the wiper and ground):



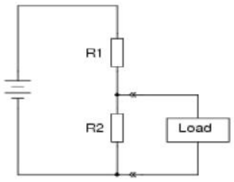
VR2max= ....
VR2min= ....

8. Calculate both the maximum and the minimum amount of voltage that each of the voltmeters will register, at each of the potentiometer's extreme positions:

VR1max=……… volts
VR1min= ……… volts
VR3max= ……… volts
VR3min= ……… volts



9. When the R3=0, what will happen to the voltages across resistors R1 and R2 when the load is connected to the divider circuit?



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……………………………………………………………………………………………………
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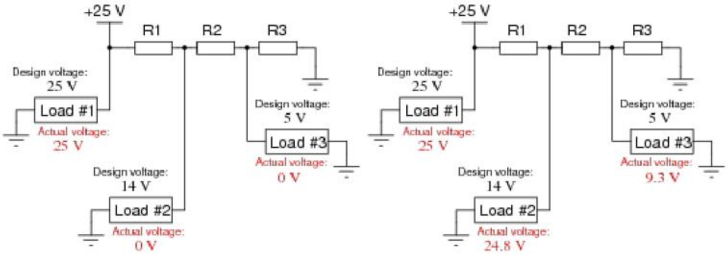
……………………………………………………………………………………………………

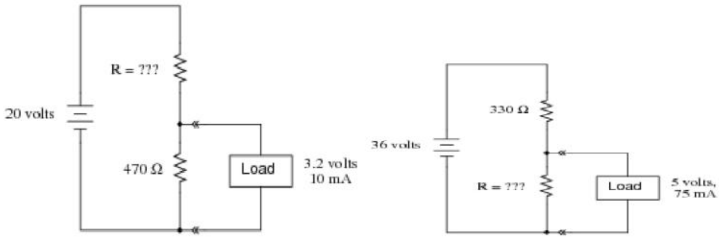
10. When the R1 =5 kΩ potentiometer R3 and R2 equal zero in this circuit is set to its 0%, 25%, 50%, 75%, and 100% positions, the following output voltages are obtained (measured with respect to ground, of course):

At 0% setting, V_{out} = ……V
At 25% setting, V_{out} = ……V
At 50% setting, V_{out} = ……V
At 75% setting, V_{out} = ……V
At 100% setting, V_{out} = …. V

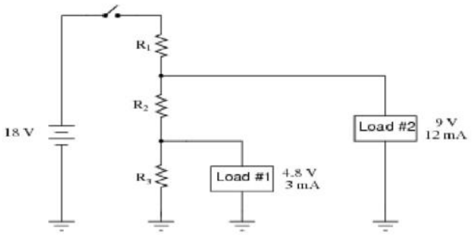
11. One of the resistors in this voltage divider circuit is failed open or short. Based on the voltage readings shown at each load, determine which one it is. Discuss with your team How can you able to predict which resistor is the faulty resistor. Is there any particular clue in the diagram indicating resistor as the obvious problem?



12. Size the resistor in this voltage divider circuit to provide 3.2 volts to the load, assuming that the load will draw 10 mA of current at this voltage:



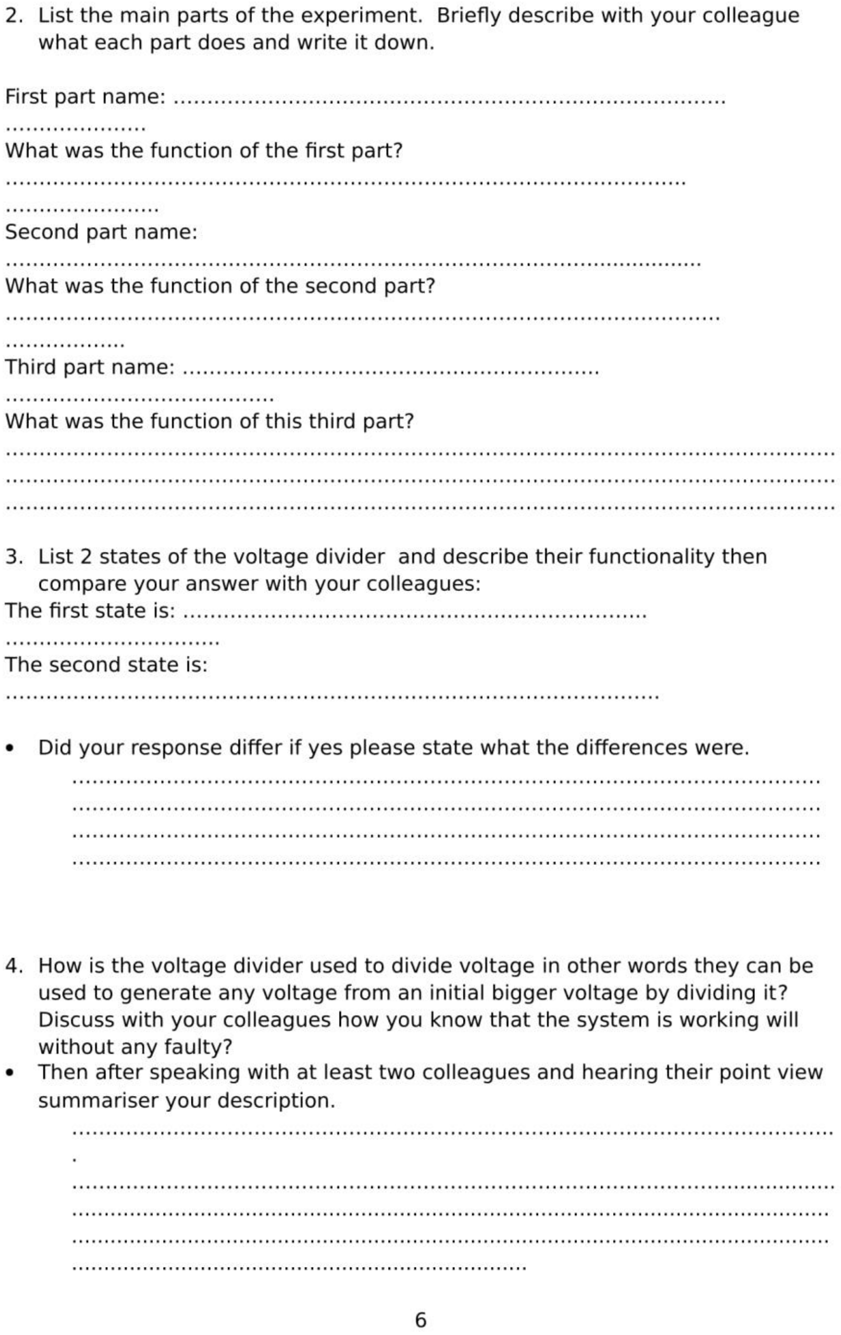
13. Size all three resistors in this voltage divider circuit to provide the necessary voltages to the loads, given the load voltage and current specifications shown:



Analysis

Next when you have finished the activities above, discuss the following questions:

1. Share your thought about your experience doing this experiment :
   ………
   ………
   ………



2. List the main parts of the experiment. Briefly describe with your colleague what each part does and write it down.

First part name: ………………………………………………………………………… …………………

What was the function of the first part?

………………………………………………………………………………………… ……………………

Second part name:

…………………………………………………………………………………………

What was the function of the second part?

………………………………………………………………………………………… ………………

Third part name: …………………………………………………… …………………………………

What was the function of this third part?

………

………

………

3. List 2 states of the voltage divider and describe their functionality then compare your answer with your colleagues:

The first state is: …………………………………………………………… ……………………………

The second state is:

………………………………………………………………………………………

- Did your response differ if yes please state what the differences were.

  ………………………………………………………………………………………………
  ………………………………………………………………………………………………
  ………………………………………………………………………………………………
  ………………………………………………………………………………………………

4. How is the voltage divider used to divide voltage in other words they can be used to generate any voltage from an initial bigger voltage by dividing it? Discuss with your colleagues how you know that the system is working will without any faulty?

- Then after speaking with at least two colleagues and hearing their point view summariser your description.

  ………………………………………………………………………………………………….
  ………………………………………………………………………………………………
  ………………………………………………………………………………………………
  ………………………………………………………………………………………………
  ……………………………………………………………

6

5. Think what else about you have learned by doing this experiment.
That is what have you learned together as a team about "Voltage divider"?
In peers share your thoughts on this and then report back to the group. Check with the group before writing your answer.
In this session you have been working collaboratively what were the 3 to 5 strategies that you found helpful?

1) …………………………………………………………………………………………………….
2) …………………………………………………………………………………………………….
3) …………………………………………………………………………………………………….
4) ……………………………………………………………………………………………………
5) ……………………………………………………………………………………………………

Were there any challenges please list the 3 to 5 that you see as most important.

1) …………………………………………………………………………………………………….
2) …………………………………………………………………………………………………….
3) …………………………………………………………………………………………………….
4) ……………………………………………………………………………………………………
5) ……………………………………………………………………………………………………

Evaluation and reflection

Thinking about your future work as an engineer what key knowledge and skills have you learned about the voltage divider used in this experiment?

……
……
……
…………………………………………………………………

Have you learned anything about 'collaboration' that has enabled you to complete this experiment? What was it?
……
……
……
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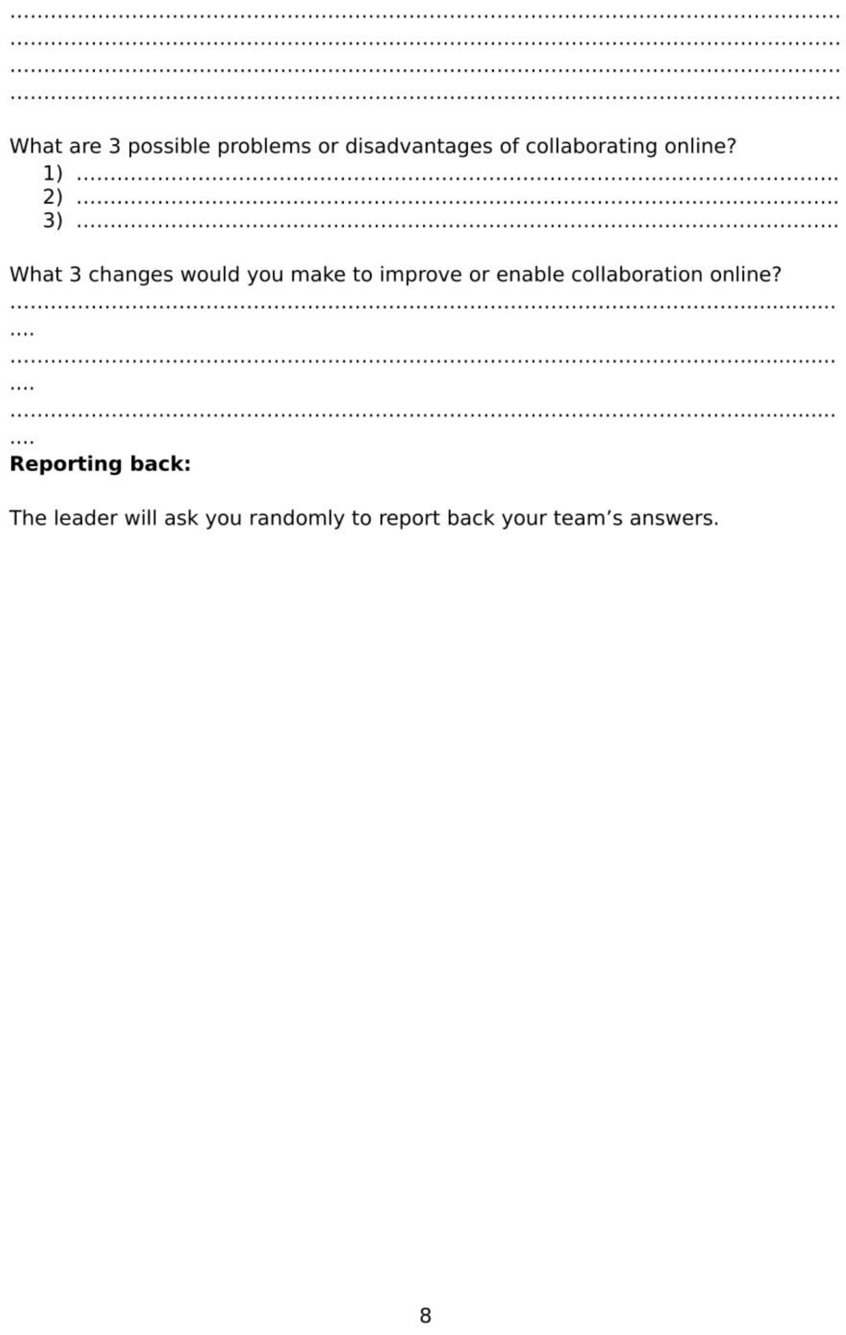
Were there any challenges? What was difficult?



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………

What are 3 possible problems or disadvantages of collaborating online?

1) ……………………………………………………………………………………………………
2) ……………………………………………………………………………………………………
3) ……………………………………………………………………………………………………

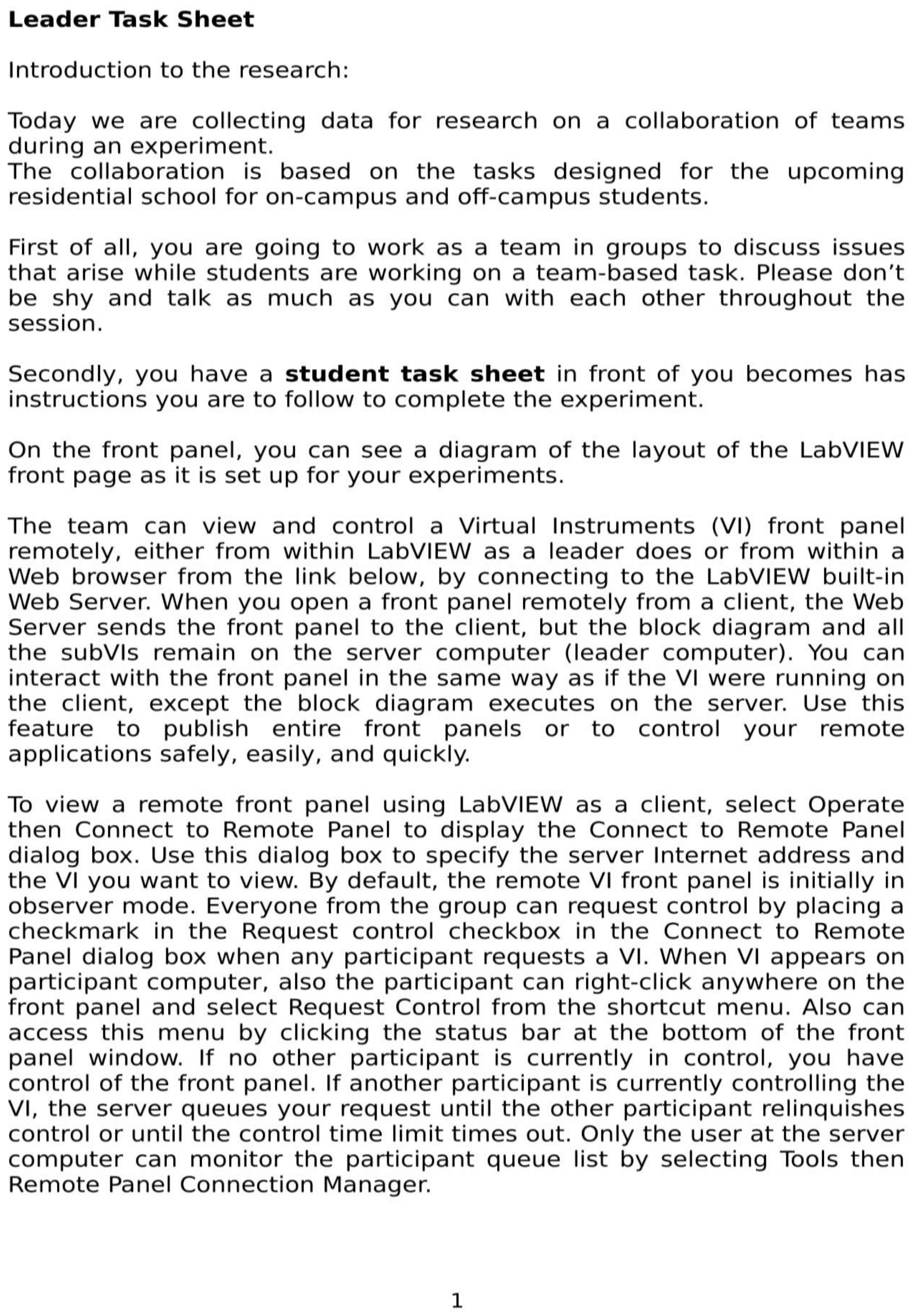
What 3 changes would you make to improve or enable collaboration online?

…….
…….
…….

Reporting back:

The leader will ask you randomly to report back your team’s answers.

Appendix B: Leader task sheet



Leader Task Sheet

Introduction to the research:

Today we are collecting data for research on a collaboration of teams during an experiment.
The collaboration is based on the tasks designed for the upcoming residential school for on-campus and off-campus students.

First of all, you are going to work as a team in groups to discuss issues that arise while students are working on a team-based task. Please don't be shy and talk as much as you can with each other throughout the session.

Secondly, you have a **student task sheet** in front of you becomes has instructions you are to follow to complete the experiment.

On the front panel, you can see a diagram of the layout of the LabVIEW front page as it is set up for your experiments.

The team can view and control a Virtual Instruments (VI) front panel remotely, either from within LabVIEW as a leader does or from within a Web browser from the link below, by connecting to the LabVIEW built-in Web Server. When you open a front panel remotely from a client, the Web Server sends the front panel to the client, but the block diagram and all the subVIs remain on the server computer (leader computer). You can interact with the front panel in the same way as if the VI were running on the client, except the block diagram executes on the server. Use this feature to publish entire front panels or to control your remote applications safely, easily, and quickly.

To view a remote front panel using LabVIEW as a client, select Operate then Connect to Remote Panel to display the Connect to Remote Panel dialog box. Use this dialog box to specify the server Internet address and the VI you want to view. By default, the remote VI front panel is initially in observer mode. Everyone from the group can request control by placing a checkmark in the Request control checkbox in the Connect to Remote Panel dialog box when any participant requests a VI. When VI appears on participant computer, also the participant can right-click anywhere on the front panel and select Request Control from the shortcut menu. Also can access this menu by clicking the status bar at the bottom of the front panel window. If no other participant is currently in control, you have control of the front panel. If another participant is currently controlling the VI, the server queues your request until the other participant relinquishes control or until the control time limit times out. Only the user at the server computer can monitor the participant queue list by selecting Tools then Remote Panel Connection Manager.

1

The circuit is already written and you must access it from this link below: **http://10.31.134.40:8000/voltagedivider.html**

If the web browser does not yet appear, the leader of your team must go to the access link:

http://10.31.134.40:8000/voltagedivider.html

Leader – observe the individuals and check they are participating.

Procedure – task sheet instructions
Now, follow the instructions to the **Activities** below in sequence and write your observations in the spaces provided for the 11 tasks. Talk with your colleagues in the group as you are working out the answers and checking with each other to write the correct answers:

1. **Go to webpage http://10.31.134.40:8000/voltagedivider.html**

   The circuit has been connected the made-up on LabVIEW as follows:

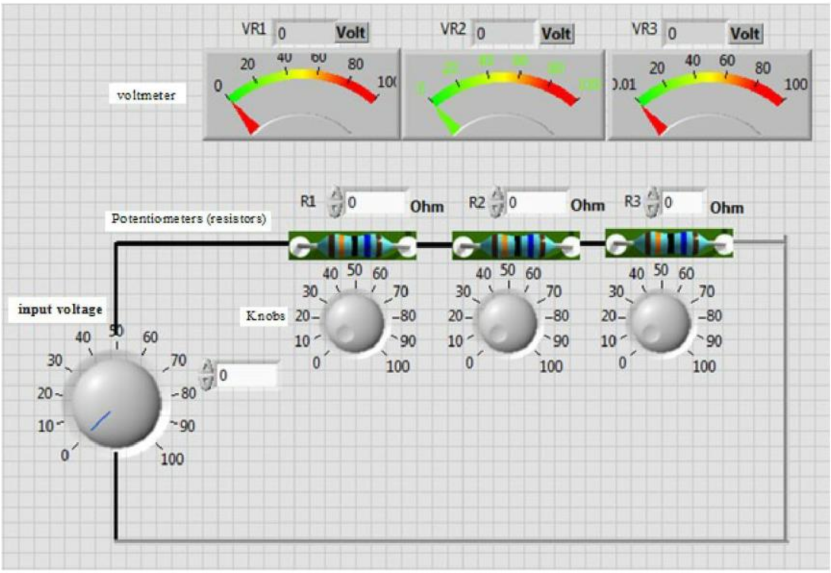

VR1 0 Volt
VR2 0 Volt
VR3 0 Volt
R1 0 Ohm
R2 0 Ohm
R3 0 Ohm
input voltage 0

Figure (1) LabVIEW front page

- Power with voltages between 0 V and 100 V.

- Potentiometer (resistors R1, R2, and R3) has been connected.
- Monitor the Volt for each resistor with voltameter.
- Ensure that there is a power-on voltage in (V in).

2. Apply input voltage of between 0 to 100 volts from the nob to the INPUT and will be monitor on the knob and digital number beside the knob as on figure (1).
    - Monitor the OUTPUT with the digital voltmeter.

3. Check that the voltage divider works correctly by doing the following:

- Ensure that the VR1, VR 2 and VR 3) (voltage crosses resistors) are still operating.
- Adjust the input voltage from the dial as shown in figure 1. You should see the voltage changes according to the input voltage and the value of resistors on the voltameters.
- Now vary the input voltage of the from the dial-up and down by hand and observe the following:
    - The voltage across each resistor; and
    - The voltage difference between the tree resistors varies from about 0 to maximum voltage on each resistor.
    - In this case, there are 3 significant output voltage: VR1, VR2, and VR3.

4. A LabVIEW program has been written and can be accessed from the link below (http://10.31.134.40:8000/voltagedivider.html):

- Sweep the Potentiometer (resisters) continuously up and down over a range which includes the entire range during which maximum and minimum voltage to each resistor on is achieved.
- On-screen display of the OUTPUT voltage crosses each resistor which should look similar to the calculation result.
- Use the voltmeter as shone on front panel to measure VR1, VR2, and VR3 and compare them with the theory (calculations method)
- On remote computer measure the voltage V input applied across the series pair of resistors. The front panel figure (1) of LabVIEW will display numerical values for each of the following parameters:
    - The input voltage
    - Resistor 1,2 and 3
    - The voltage across each resistor VR1, VR2, and VR3
- Sweep all three alternative resistors through the Knobs.

5. In the event that time is still available, measure and display the VR1, VR2, VR3, R1,R2and R3:

- Sweep the Potentiometers (resistors) over to get the voltage that crosses each resistor.

As the following

R1 ten-time R2 R3 equal zero.

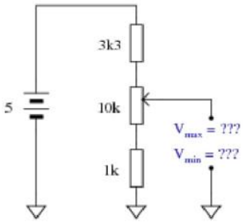
R1 the same value R2, R3 equal zero.

R1 Half value R2, R3 double-time R2.

6. Does the voltage divider appear to be work at this point? Why?

……
.
……
.
……
.
………………………………………………………………………………………
…………………
………………………………………………………………………………………
…………………

7. R2=3.3k Ω and R3=1k Ω as shown below. Calculate both the maximum and the minimum amount of voltage obtainable from this potentiometer circuit (as measured between the wiper and ground):

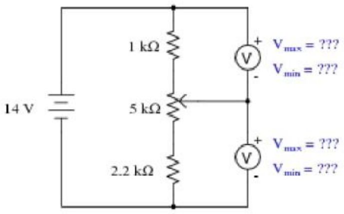


VR2max= ………………….
VR2min= ………………….

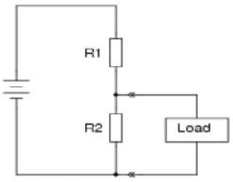
8. Calculate both the maximum and the minimum amount of voltage that each of the voltmeters will register, at each of the potentiometer's extreme positions:

VR1max=………volts
VR1min= ………volts
VR3max= ………volts

VR3min= .... volts



9. When the R3=0, what will happen to the voltages across resistors R2, when R1 becomes 10 times R2 when the load is connected to the divider circuit?



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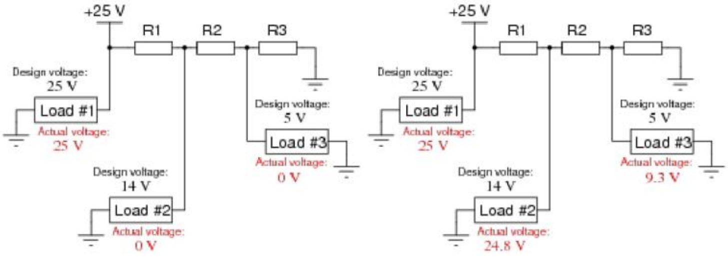
....

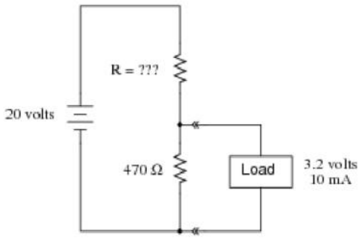
10. When the R1 =5 kΩ potentiometer R3 and R2 equal zero in this circuit is set to its 0%, 25%, 50%, 75%, and 100% positions, the following output voltages are obtained (measured with respect to ground, of course):

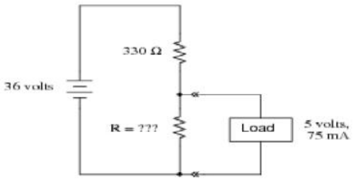
At 0% setting, V_{out} = ...V
At 25% setting, V_{out} = ...V
At 50% setting, V_{out} = ...V
At 75% setting, V_{out} = ...V
At 100% setting, V_{out} = ... V

11. One of the resistors in this voltage divider circuit is failed open or short. Based on the voltage readings shown at each load, determine which one it is. Discuss with your team How can you able to predict which resistor is the faulty resistor. Is there any particular clue in the diagram indicating resistor as the obvious problem?

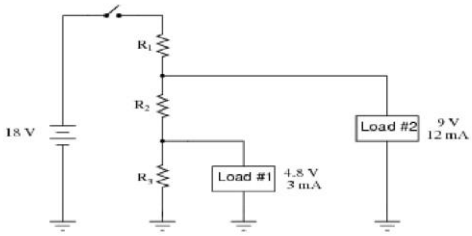


12. Size the resistor in this voltage divider circuit to provide 3.2 volts to the load, assuming that the load will draw 10 mA of current at this voltage:





13. Size all three resistors in this voltage divider circuit to provide the necessary voltages to the loads, given the load voltage and current specifications shown:



Analysis

Next, when you have finished the activities above, discuss the following questions:

1. Share your thought about your experience doing this experiment :
   ………
   ………
   ………

2. List 2 stages of the voltage divider and describe their functionality then compare your answer with your colleagues:

The first state is: ……………………………………………………………
……………………………
The second state is:
………………………………………………………………………………………

- Did your response differ if yes please state what the differences were?
  ……
  ……
  ……
  ……

3. How is the voltage divider used to divide voltage in other words they can be used to generate any voltage from an initial bigger voltage by dividing it? Discuss with your colleagues how you know that the system is working well without any faulty?

- Then after speaking with at least two colleagues and hearing their point of view summarise your description.
  ………
  .
  ………
  ………
  ………
  ……………………………………………………………

4. Think of what else about you have learned by doing this experiment.
That is what have you learned together as a team about “Voltage divider”?
In peers share your thoughts on this and then report back to the group. Check with the group before writing your answer.
In this session, you have been working collaboratively what were the 3 to 5 strategies that you found helpful?

1) …………………………………………………………………………………………………….
2) …………………………………………………………………………………………………….
3) …………………………………………………………………………………………………….
4) ……………………………………………………………………………………………………
5) ……………………………………………………………………………………………………

Were there any challenges please list the 3 to 5 that you see as most important.

1) …………………………………………………………………………………………………….
2) …………………………………………………………………………………………………….
3) …………………………………………………………………………………………………….
4) ……………………………………………………………………………………………………
5) ……………………………………………………………………………………………………

Evaluation and reflection

Thinking about your future work as an engineer what key knowledge and skills have you learned about the voltage divider used in this experiment?

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……
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…………………………………………………………………………

Have you learned anything about 'collaboration' that has enabled you to complete this experiment? What was it?
……
……
……
…………

Were there any challenges? What was difficult?
……
……
……
……

What are 3 possible problems or disadvantages of collaborating online?

1) ……………………………………………………………………………………………………
2) ……………………………………………………………………………………………………
3) ……………………………………………………………………………………………………

What 3 changes would you make to improve or enable collaboration online?

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....

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....

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....

Reporting back:

As the leader asks the students randomly to report back their team’s answers. (Note: the random number to call out is in brackets beside each question. If there the group is more than 3 students propose the number randomly).

Appendix C: Invitation to Participate in a Research Study

Get prepared for laboratory activity experience

INVITATION TO PARTICIPATE IN A RESEARCH STUDY:

COLLABORATION IN REMOTE ACCESS LABORATORY

You are invited to participate in this research study which is being carried out by Ali Habibi from the engineering education research Program at the University of Southern Queensland

Human Research Ethics Approval Number: H17REA256

WHY

It is about you finding out before the course start, how to access the laboratory for Voltage divider you will experience group collaboration with your colleagues at USQ.

WHEN

April 10-15

WHO CAN PARTICIPATE?

USQ students enrolled practical courses: engineering and physics. Choose a partner or as individual.

WHAT IS INVOLVED?

Practice run for your Lab work for 2 hours to your advantage.

An interview that will take up to 30 minutes after the lab or a time to convenient you to you, by zoom conference or phone or face-to-face at USQ.

WHAT IS THE STUDY ABOUT?

In this study we are interested in finding out and develop an instructional framework that supports Collaboration in a Remote Access Laboratory (RAL) environment, utilising Doolittle's theoretical framework for collaboration and developing it further in the context of RAL. The instructional principles will be tested with a number of RAL learning activities. This research will identify enablers and inhibitors of effective collaboration in the given context.

PARTICIPATION IS VOLUNTARY AND CONFIDENTIAL

You may like to take advantage of a practice run for your Lab work. To find out more

Please contact Ali Mohamed Habibi

If you would like to participate, please contact the researcher before 10 April 2018 to secure your place (Participation is free and limited places available).

TO APPLY AND FOR FURTHER INFORMATION:

Phone Ali Mohamed Habibi

On 0401505820 or

Email: *AliMohamed.Habibi@usq.edu.au*

Appendix D: Invitation to Participate by Blog on a Web Page

Collaboration in Remote Access Laboratory

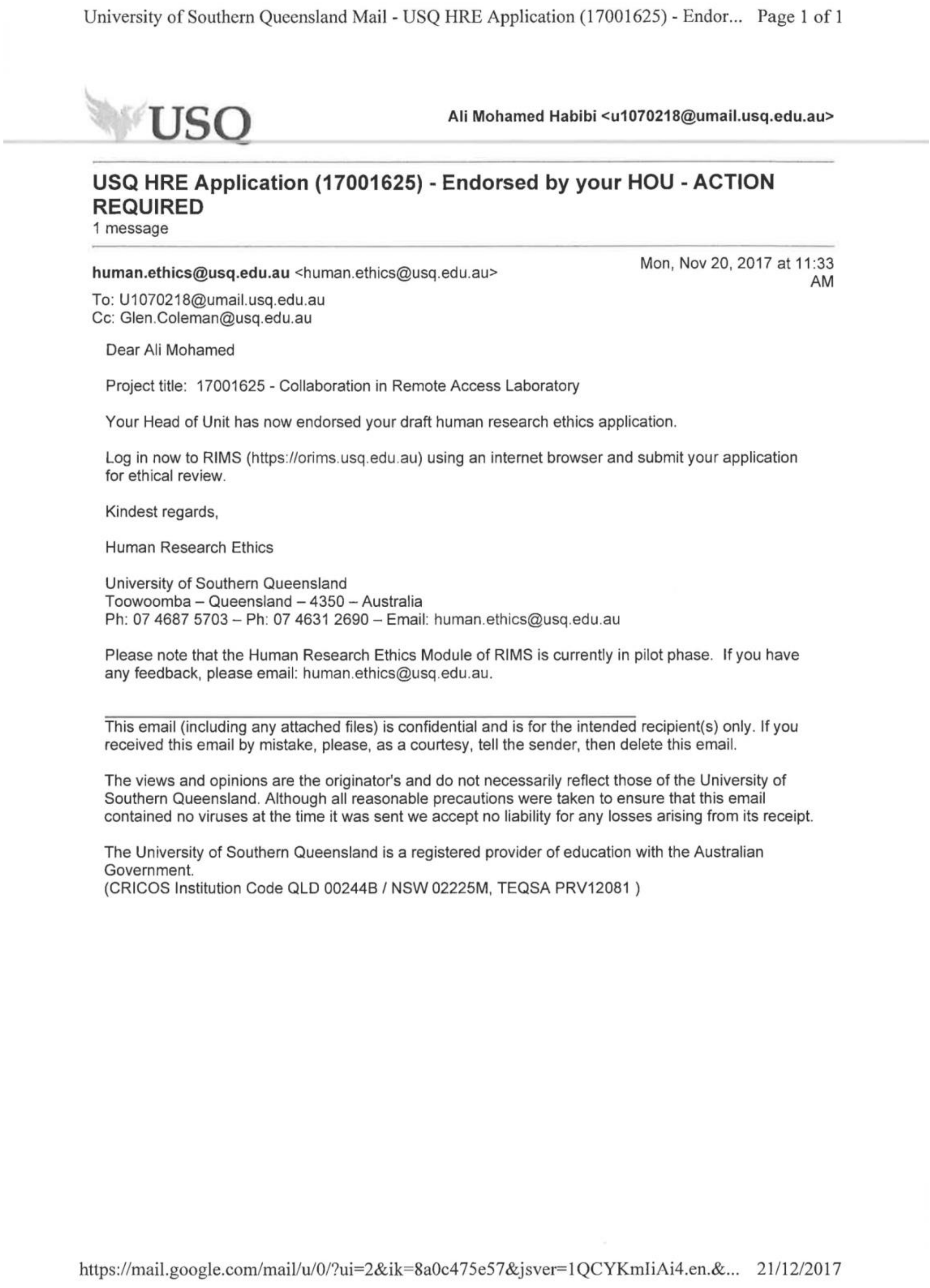
- July 03, 2018

Get prepared for laboratory activity experience

INVITATION TO PARTICIPATE IN A RESEARCH STUDY:
COLLABORATION IN REMOTE ACCESS LABORATORY

Location: West St, Darling Heights QLD 4350, Australia

Appendix E: Head of Unit Endorsement



University of Southern Queensland Mail - USQ HRE Application (17001625) - Endor... Page 1 of 1

USQ

Ali Mohamed Habibi <u1070218@umail.usq.edu.au>

USQ HRE Application (17001625) - Endorsed by your HOU - ACTION REQUIRED

1 message

human.ethics@usq.edu.au <human.ethics@usq.edu.au> Mon, Nov 20, 2017 at 11:33 AM

To: U1070218@umail.usq.edu.au
Cc: Glen.Coleman@usq.edu.au

Dear Ali Mohamed

Project title: 17001625 - Collaboration in Remote Access Laboratory

Your Head of Unit has now endorsed your draft human research ethics application.

Log in now to RIMS (https://orims.usq.edu.au) using an internet browser and submit your application for ethical review.

Kindest regards,

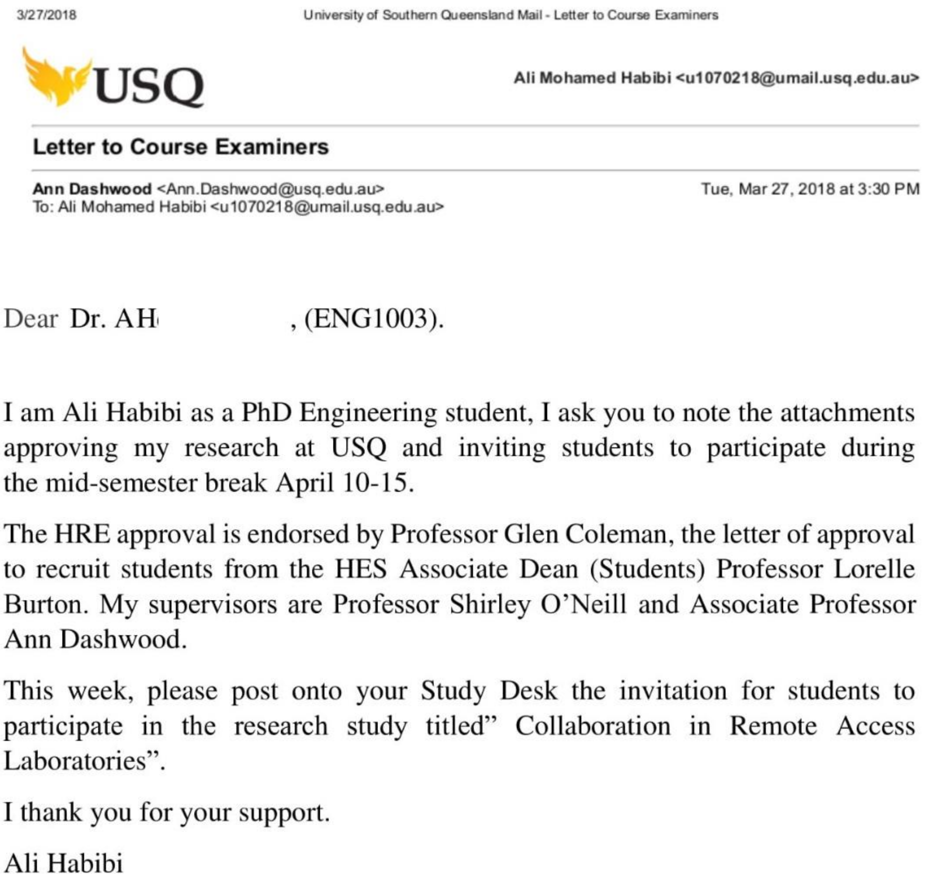
Human Research Ethics

University of Southern Queensland
Toowoomba – Queensland – 4350 – Australia
Ph: 07 4687 5703 – Ph: 07 4631 2690 – Email: human.ethics@usq.edu.au

Please note that the Human Research Ethics Module of RIMS is currently in pilot phase. If you have any feedback, please email: human.ethics@usq.edu.au.

https://mail.google.com/mail/u/0/?ui=2&ik=8a0c475e57&jsver=1QCYKmIiAi4.en.&... 21/12/2017

Appendix F: Letter to Course Examiner



3/27/2018 University of Southern Queensland Mail - Letter to Course Examiners

USQ

Ali Mohamed Habibi <u1070218@umail.usq.edu.au>

Letter to Course Examiners

Ann Dashwood <Ann.Dashwood@usq.edu.au> Tue, Mar 27, 2018 at 3:30 PM
To: Ali Mohamed Habibi <u1070218@umail.usq.edu.au>

Dear Dr. AH[redacted], (ENG1003).

I am Ali Habibi as a PhD Engineering student, I ask you to note the attachments approving my research at USQ and inviting students to participate during the mid-semester break April 10-15.

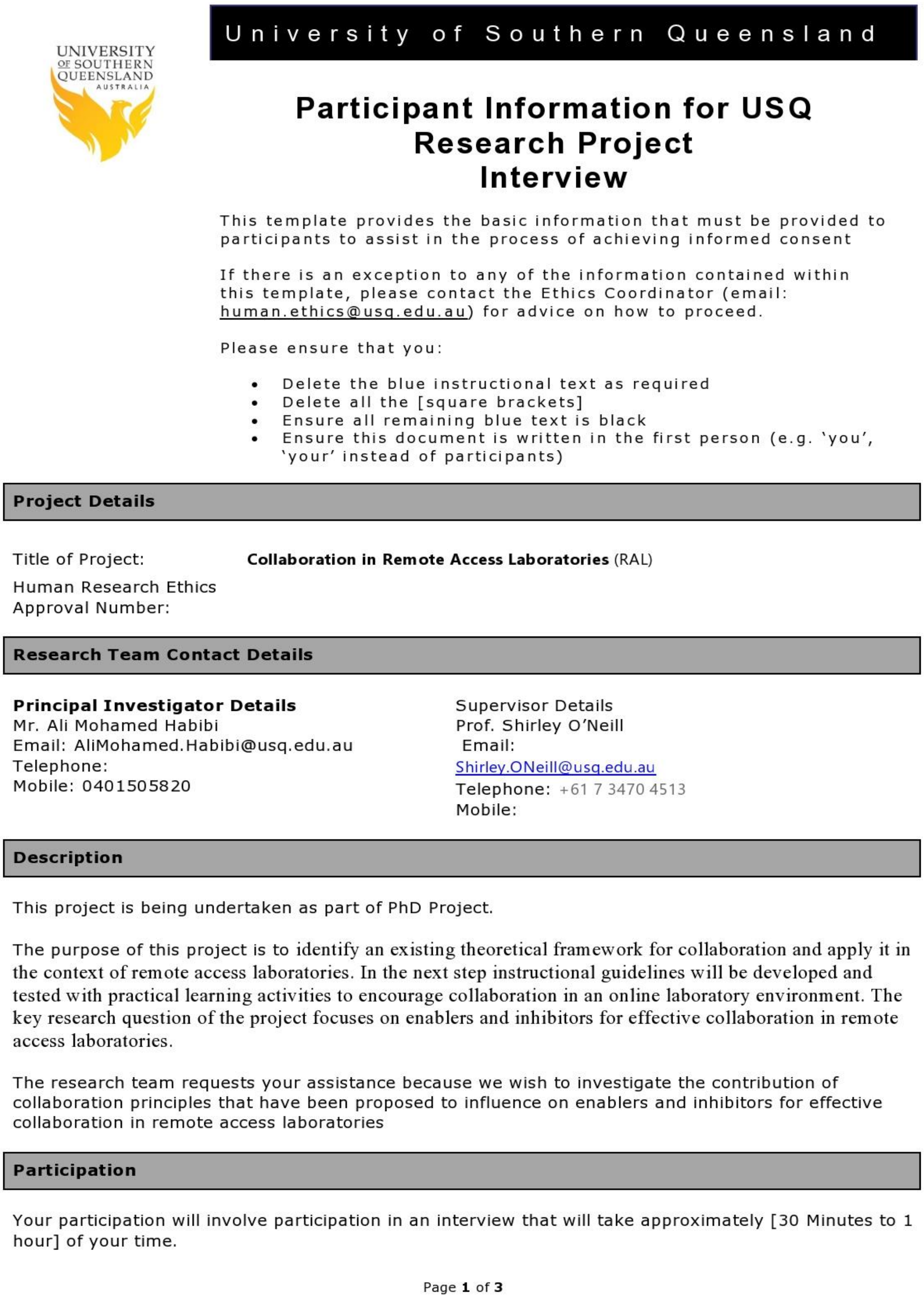
The HRE approval is endorsed by Professor Glen Coleman, the letter of approval to recruit students from the HES Associate Dean (Students) Professor Lorelle Burton. My supervisors are Professor Shirley O'Neill and Associate Professor Ann Dashwood.

This week, please post onto your Study Desk the invitation for students to participate in the research study titled" Collaboration in Remote Access Laboratories".

I thank you for your support.

Ali Habibi

Appendix G: Participants Interview Information Sheet



University of Southern Queensland

UNIVERSITY OF SOUTHERN QUEENSLAND AUSTRALIA

Participant Information for USQ Research Project Interview

This template provides the basic information that must be provided to participants to assist in the process of achieving informed consent

If there is an exception to any of the information contained within this template, please contact the Ethics Coordinator (email: human.ethics@usq.edu.au) for advice on how to proceed.

Please ensure that you:

- Delete the blue instructional text as required
- Delete all the [square brackets]
- Ensure all remaining blue text is black
- Ensure this document is written in the first person (e.g. 'you', 'your' instead of participants)

Project Details

Title of Project: **Collaboration in Remote Access Laboratories** (RAL)

Human Research Ethics Approval Number:

Research Team Contact Details

Principal Investigator Details
Mr. Ali Mohamed Habibi
Email: AliMohamed.Habibi@usq.edu.au
Telephone:
Mobile: 0401505820

Supervisor Details
Prof. Shirley O'Neill
Email:
Shirley.ONeill@usq.edu.au
Telephone: +61 7 3470 4513
Mobile:

Description

This project is being undertaken as part of PhD Project.

The purpose of this project is to identify an existing theoretical framework for collaboration and apply it in the context of remote access laboratories. In the next step instructional guidelines will be developed and tested with practical learning activities to encourage collaboration in an online laboratory environment. The key research question of the project focuses on enablers and inhibitors for effective collaboration in remote access laboratories.

The research team requests your assistance because we wish to investigate the contribution of collaboration principles that have been proposed to influence on enablers and inhibitors for effective collaboration in remote access laboratories

Participation

Your participation will involve participation in an interview that will take approximately [30 Minutes to 1 hour] of your time.

Page **1** of **3**

The interview will be undertaken by teleconference at a date and time that is convenient to you.

Questions will include

- Does the success of one participant will benefit other participants?
- Is individual or public performance required?
- How percentage is the participation engages?
- What percent are interacting at same time?
- How did you find working collaboratively to do the task?
- What were the benefits of collaborating?
- How could carrying out this practicum be improved?
- What is your attitude towards collaborative activity?
- Why is it important to work together on a collaborative learning team?
- What would help you work better as a team?
- What could peers do to help you with activity?
- What helps to get you involved in collaboration activity?
- Does working in a collaborative activity team help get you involved in your learning? If so, why do you think that is?
- How do you participate in your collaborative activity groups?

The interview will be audio / video recorded.

Your participation in this project is entirely voluntary. If you do not wish to take part you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. You may also request that any data collected about you be destroyed. If you do wish to withdraw from this project or withdraw data collected about you, please contact the Research Team (contact details at the top of this form).

Your decision whether you take part, do not take part, or to take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland or External organisation name.

Expected Benefits

It is expected that this project will directly benefit you because the main aim of this research is to establish an instructional framework and providing recommendations for the facilitation of online collaboration via remote access laboratories. The research will focus specifically on a structural framework for collaboration between remote access laboratories. However, it could be extended to collaboration online generally. Laboratory teaching can be improved through collaboration in an online laboratory and so can enhance learning outcomes. Online collaboration will be a part of future teaching in an online environment. Collaboration in RAL can play a key role in positively influencing the outcomes of participant learning. Also it is designed to encourage participants to undertake speed of interaction; experience clear articulation of expectations and timeliness of feedback; engage participants to share their ideas by interacting, and have the opportunity to discuss results and so enhance outcomes.

Risks

Choose one of the following options (refer to responses provided in 1A.9 – 1A.13 of the ethics application:

There are no anticipated risks beyond normal day-to-day living associated with your participation in this project.

Privacy and Confidentiality

All comments and responses will be treated confidentially unless required by law.

For audio or video recording Information should also be provided to inform a participant:

- If the interviews will be audio and/ or video recorded.
- If they will be provided with a copy of the interview transcript for review and endorsement prior to inclusion in the project data
- The expected time frame they will be given to review and request any changes to the transcript before the data is included in the project (i.e. two weeks).
- If the recording will be used for any other purpose (i.e. as a teaching/ instructional tool)
- Who will have access to the recording, including who may be involved in the transcribing of the recording (if this will be conducted by a person or persons outside of those listed as investigators for this project)?
- Whether it is possible to participate in the project without being recorded.

Include a statement about how data collected may be used in future research.*(please note in accordance with 2.5.2 of the "Australian Code for the Responsible Conduct of Research", research data should be made available for use by other researchers unless this is prevented by ethical, privacy or confidentiality matters).*

Include details about how participants will be provided with or how they can access the project summary of results (*in accordance with 4.4.3 of the Australian Code for the Responsible Conduct of Research, researchers must where feasible, must also provide research participants with an appropriate summary of the research results*).

If the project is funded by an external third party, you will need to inform participants of this. No statement is required if the project is self (or University) funded.

Any data collected as a part of this project will be stored securely as per University of Southern Queensland's Research Data Management policy.

Consent to Participate

We would like to ask you to sign a written consent form (enclosed) to confirm your agreement to participate in this project. Please return your signed consent form to a member of the Research Team prior to participating in your interview.

Questions or Further Information about the Project

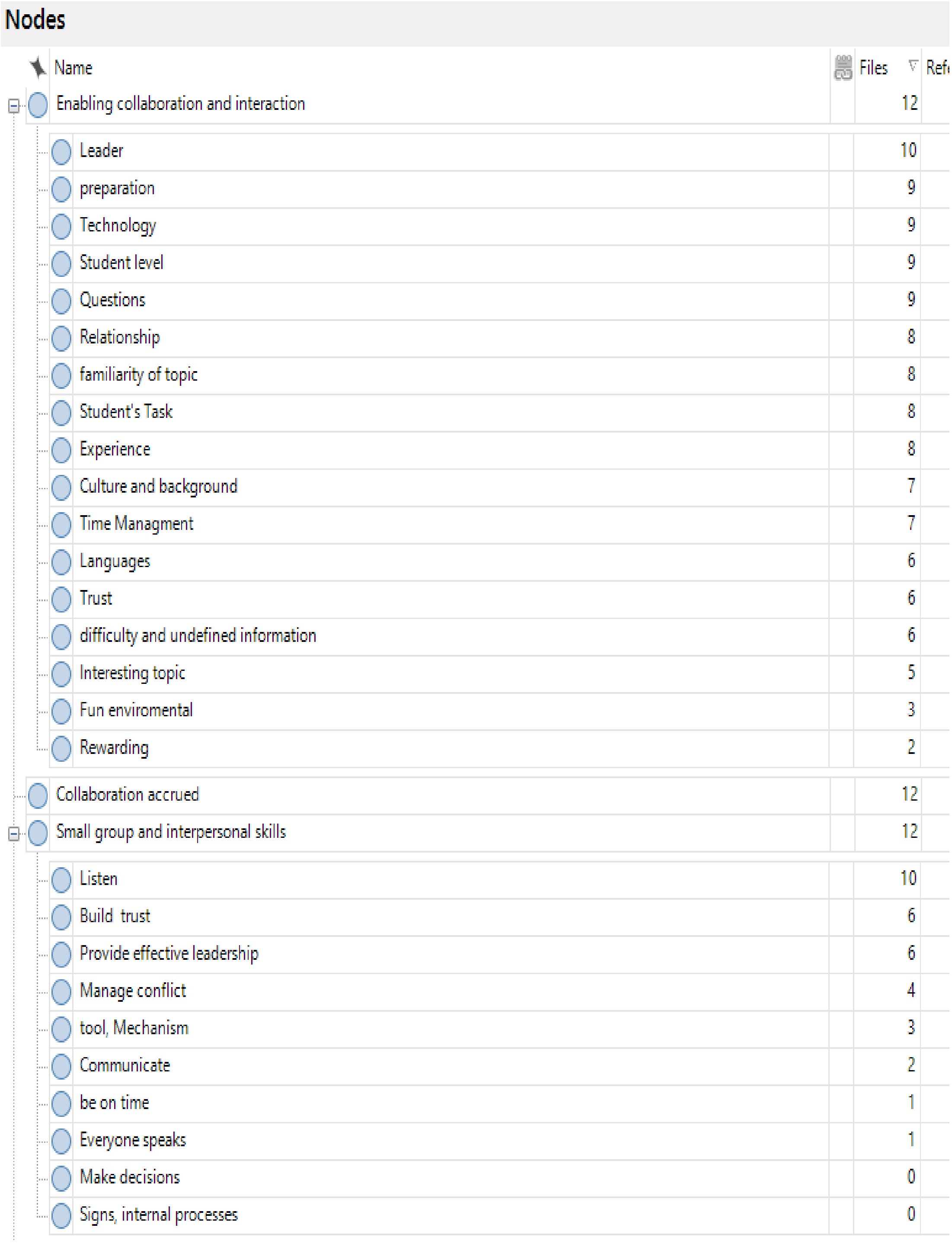
Please refer to the Research Team Contact Details at the top of the form to have any questions answered or to request further information about this project.

Concerns or Complaints Regarding the Conduct of the Project

If you have any concerns or complaints about the ethical conduct of the project you may contact the University of Southern Queensland Manager of Research Integrity and Ethics on +61 7 4631 2214 or email researchintegrity@usq.edu.au. The Manager of Research Integrity and Ethics is not connected with the research project and can facilitate a resolution to your concern in an unbiased manner.

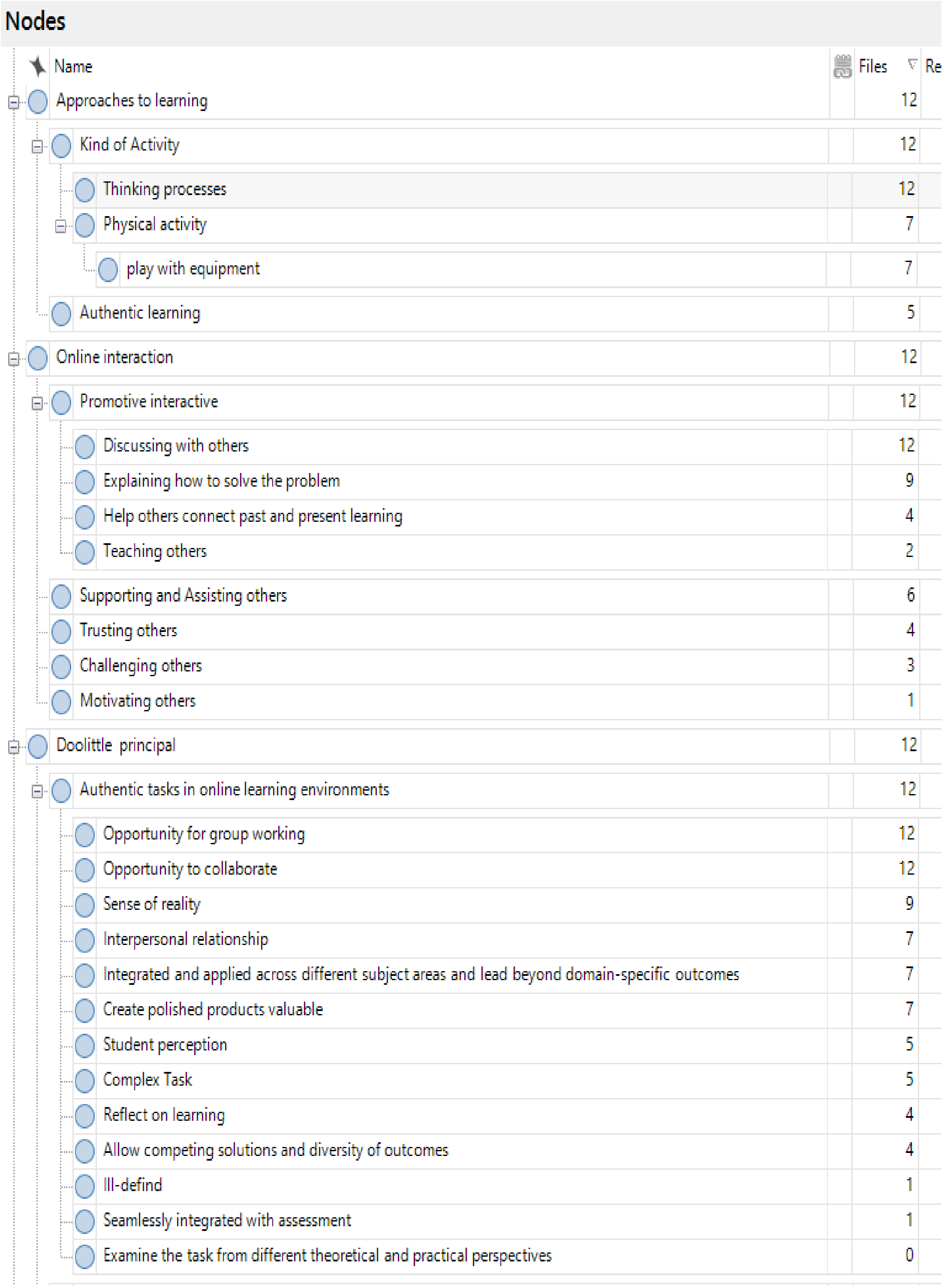
Thank you for taking the time to help with this research project. Please keep this sheet for your information.

Appendix H: Nodes on NVivo Software



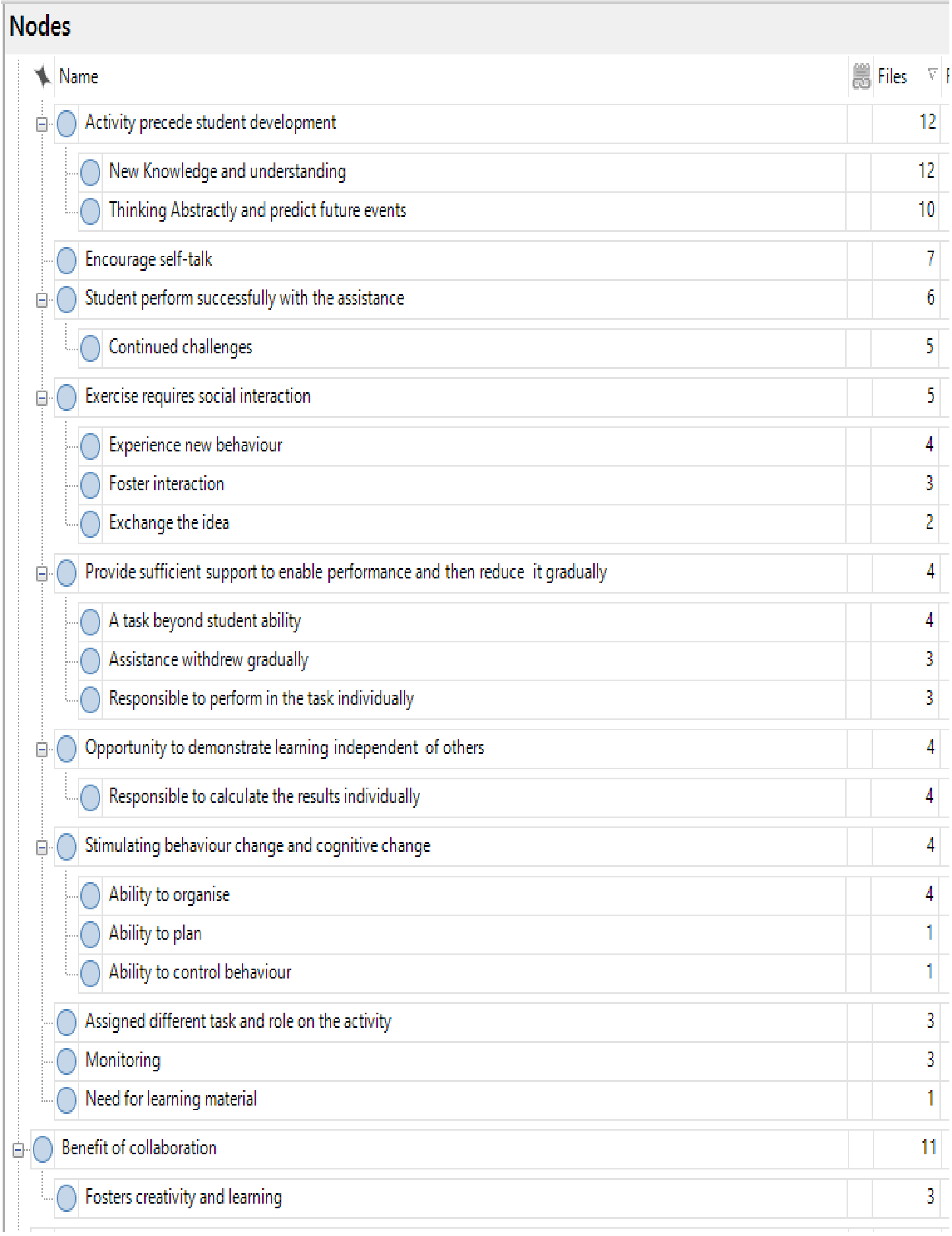
Nodes

Name	Files	Refe
Enabling collaboration and interaction	12	
Leader	10	
preparation	9	
Technology	9	
Student level	9	
Questions	9	
Relationship	8	
familiarity of topic	8	
Student's Task	8	
Experience	8	
Culture and background	7	
Time Managment	7	
Languages	6	
Trust	6	
difficulty and undefined information	6	
Interesting topic	5	
Fun enviromental	3	
Rewarding	2	
Collaboration accrued	12	
Small group and interpersonal skills	12	
Listen	10	
Build trust	6	
Provide effective leadership	6	
Manage conflict	4	
tool, Mechanism	3	
Communicate	2	
be on time	1	
Everyone speaks	1	
Make decisions	0	
Signs, internal processes	0	



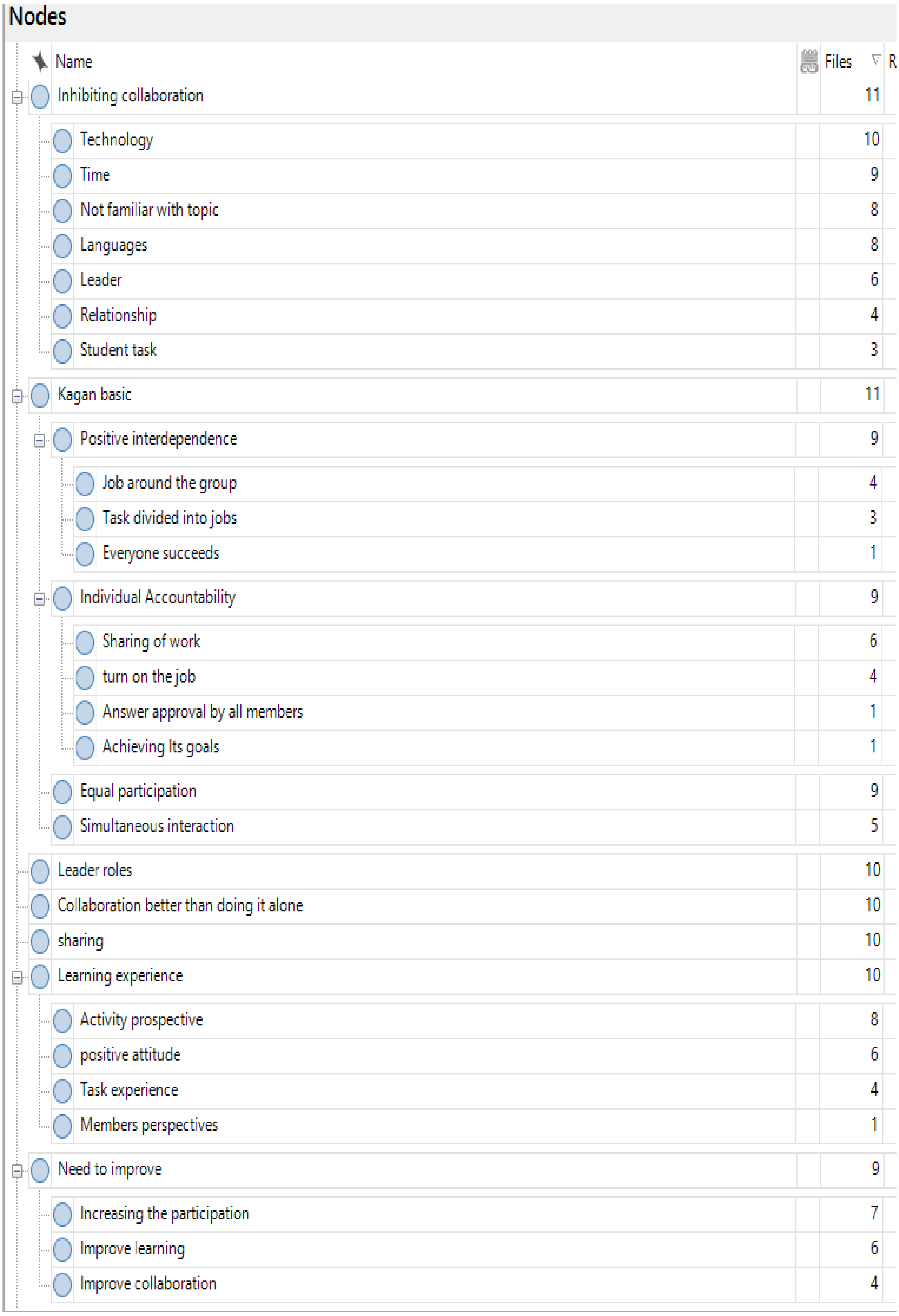
Nodes

Name	Files	Re
Approaches to learning	12	
Kind of Activity	12	
Thinking processes	12	
Physical activity	7	
play with equipment	7	
Authentic learning	5	
Online interaction	12	
Promotive interactive	12	
Discussing with others	12	
Explaining how to solve the problem	9	
Help others connect past and present learning	4	
Teaching others	2	
Supporting and Assisting others	6	
Trusting others	4	
Challenging others	3	
Motivating others	1	
Doolittle principal	12	
Authentic tasks in online learning environments	12	
Opportunity for group working	12	
Opportunity to collaborate	12	
Sense of reality	9	
Interpersonal relationship	7	
Integrated and applied across different subject areas and lead beyond domain-specific outcomes	7	
Create polished products valuable	7	
Student perception	5	
Complex Task	5	
Reflect on learning	4	
Allow competing solutions and diversity of outcomes	4	
Ill-defind	1	
Seamlessly integrated with assessment	1	
Examine the task from different theoretical and practical perspectives	0	



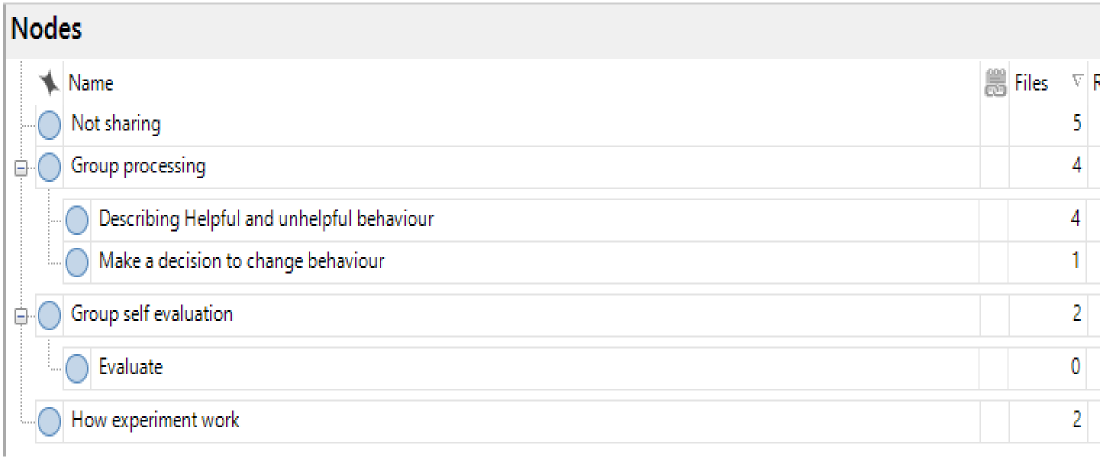
Nodes

Name	Files
Activity precede student development	12
New Knowledge and understanding	12
Thinking Abstractly and predict future events	10
Encourage self-talk	7
Student perform successfully with the assistance	6
Continued challenges	5
Exercise requires social interaction	5
Experience new behaviour	4
Foster interaction	3
Exchange the idea	2
Provide sufficient support to enable performance and then reduce it gradually	4
A task beyond student ability	4
Assistance withdrew gradually	3
Responsible to perform in the task individually	3
Opportunity to demonstrate learning independent of others	4
Responsible to calculate the results individually	4
Stimulating behaviour change and cognitive change	4
Ability to organise	4
Ability to plan	1
Ability to control behaviour	1
Assigned different task and role on the activity	3
Monitoring	3
Need for learning material	1
Benefit of collaboration	11
Fosters creativity and learning	3



Nodes

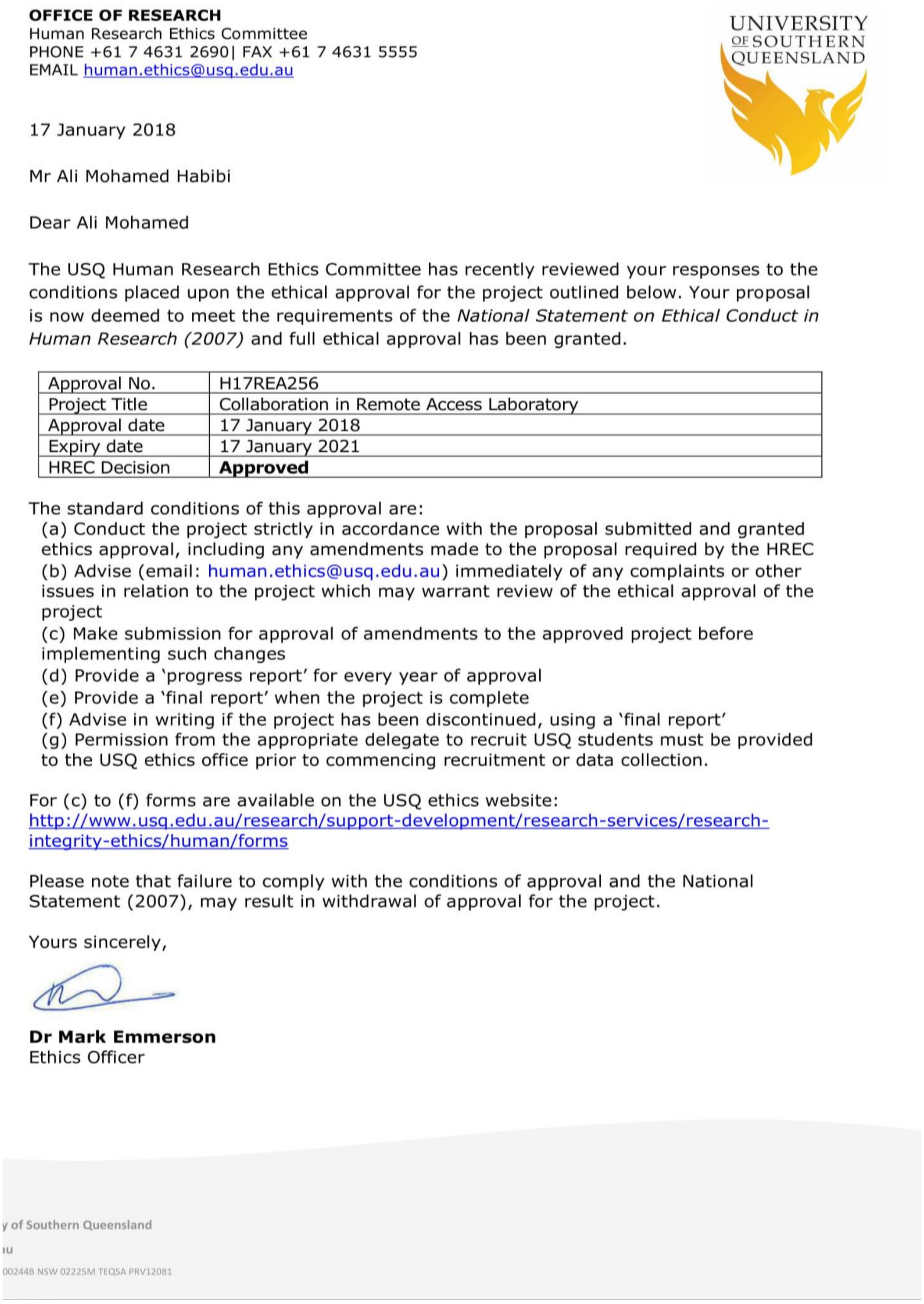
Name	Files	R
Inhibiting collaboration	11	
Technology	10	
Time	9	
Not familiar with topic	8	
Languages	8	
Leader	6	
Relationship	4	
Student task	3	
Kagan basic	11	
Positive interdependence	9	
Job around the group	4	
Task divided into jobs	3	
Everyone succeeds	1	
Individual Accountability	9	
Sharing of work	6	
turn on the job	4	
Answer approval by all members	1	
Achieving Its goals	1	
Equal participation	9	
Simultaneous interaction	5	
Leader roles	10	
Collaboration better than doing it alone	10	
sharing	10	
Learning experience	10	
Activity prospective	8	
positive attitude	6	
Task experience	4	
Members perspectives	1	
Need to improve	9	
Increasing the participation	7	
Improve learning	6	
Improve collaboration	4	



Nodes

Name	Files
Not sharing	5
Group processing	4
Describing Helpful and unhelpful behaviour	4
Make a decision to change behaviour	1
Group self evaluation	2
Evaluate	0
How experiment work	2

Appendix I: USQ HREC Approval Letter



OFFICE OF RESEARCH
Human Research Ethics Committee
PHONE +61 7 4631 2690| FAX +61 7 4631 5555
EMAIL human.ethics@usq.edu.au

UNIVERSITY OF SOUTHERN QUEENSLAND

17 January 2018

Mr Ali Mohamed Habibi

Dear Ali Mohamed

The USQ Human Research Ethics Committee has recently reviewed your responses to the conditions placed upon the ethical approval for the project outlined below. Your proposal is now deemed to meet the requirements of the *National Statement on Ethical Conduct in Human Research (2007)* and full ethical approval has been granted.

Approval No.	H17REA256
Project Title	Collaboration in Remote Access Laboratory
Approval date	17 January 2018
Expiry date	17 January 2021
HREC Decision	**Approved**

The standard conditions of this approval are:

(a) Conduct the project strictly in accordance with the proposal submitted and granted ethics approval, including any amendments made to the proposal required by the HREC
(b) Advise (email: human.ethics@usq.edu.au) immediately of any complaints or other issues in relation to the project which may warrant review of the ethical approval of the project
(c) Make submission for approval of amendments to the approved project before implementing such changes
(d) Provide a 'progress report' for every year of approval
(e) Provide a 'final report' when the project is complete
(f) Advise in writing if the project has been discontinued, using a 'final report'
(g) Permission from the appropriate delegate to recruit USQ students must be provided to the USQ ethics office prior to commencing recruitment or data collection.

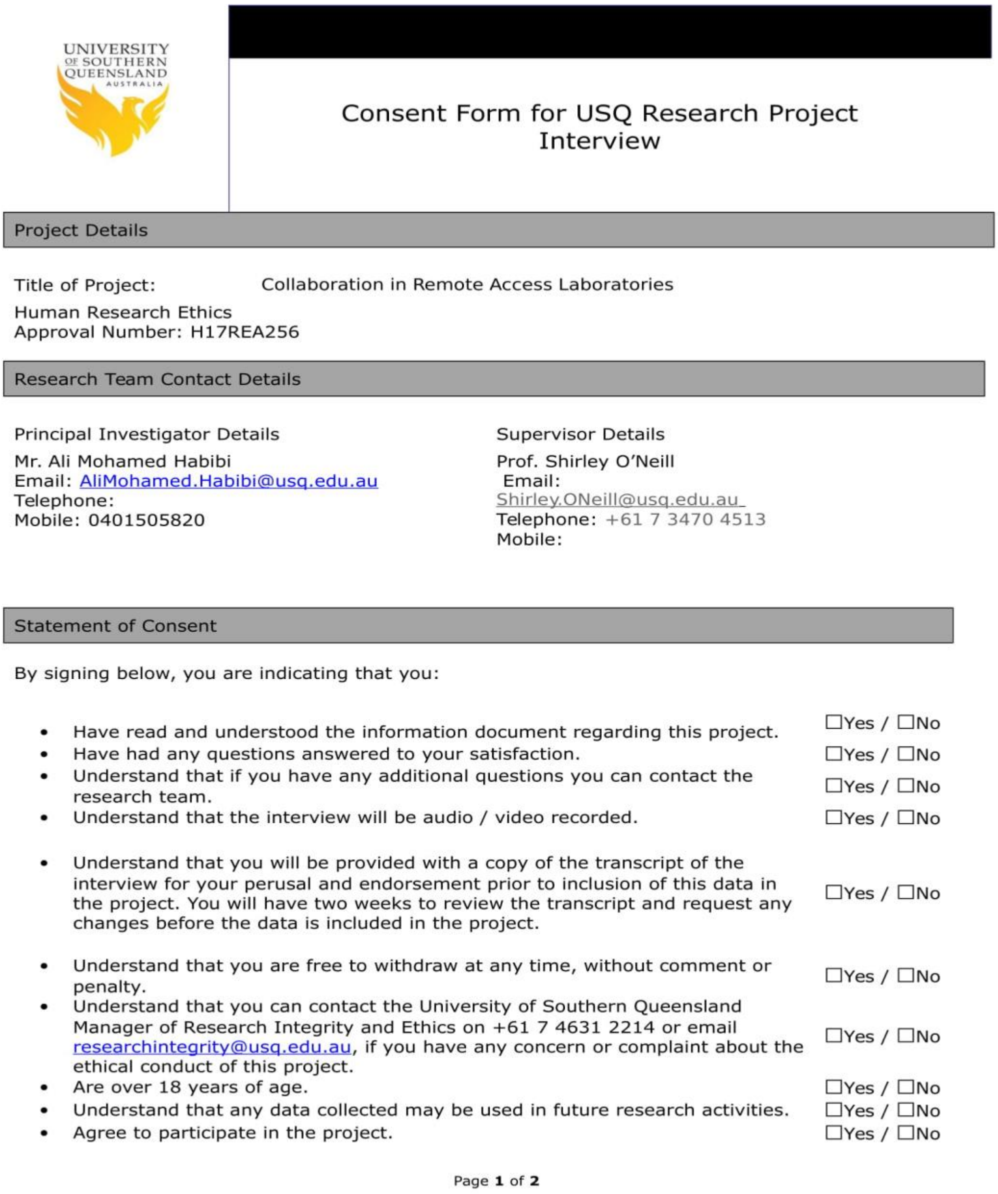
For (c) to (f) forms are available on the USQ ethics website:
http://www.usq.edu.au/research/support-development/research-services/research-integrity-ethics/human/forms

Please note that failure to comply with the conditions of approval and the National Statement (2007), may result in withdrawal of approval for the project.

Yours sincerely,

Dr Mark Emmerson
Ethics Officer

Appendix J: Interview Consent Form



UNIVERSITY OF SOUTHERN QUEENSLAND
AUSTRALIA

Consent Form for USQ Research Project Interview

Project Details

Title of Project:	Collaboration in Remote Access Laboratories
Human Research Ethics Approval Number:	H17REA256

Research Team Contact Details

Principal Investigator Details
Mr. Ali Mohamed Habibi
Email: AliMohamed.Habibi@usq.edu.au
Telephone:
Mobile: 0401505820

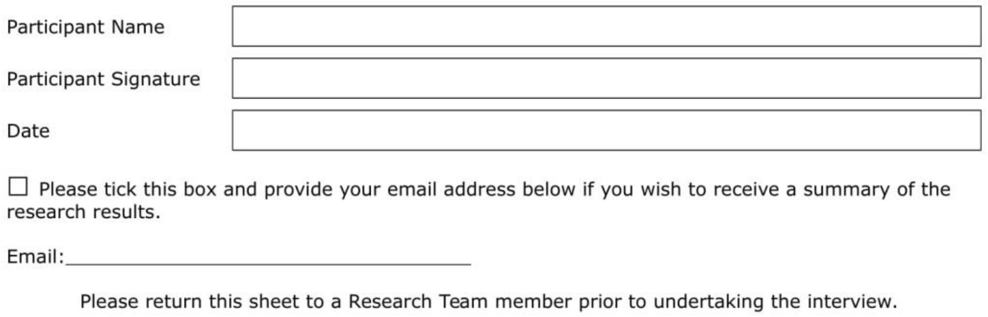
Supervisor Details
Prof. Shirley O'Neill
Email:
Shirley.ONeill@usq.edu.au
Telephone: +61 7 3470 4513
Mobile:

Statement of Consent

By signing below, you are indicating that you:

• Have read and understood the information document regarding this project.	☐Yes / ☐No
• Have had any questions answered to your satisfaction.	☐Yes / ☐No
• Understand that if you have any additional questions you can contact the research team.	☐Yes / ☐No
• Understand that the interview will be audio / video recorded.	☐Yes / ☐No
• Understand that you will be provided with a copy of the transcript of the interview for your perusal and endorsement prior to inclusion of this data in the project. You will have two weeks to review the transcript and request any changes before the data is included in the project.	☐Yes / ☐No
• Understand that you are free to withdraw at any time, without comment or penalty.	☐Yes / ☐No
• Understand that you can contact the University of Southern Queensland Manager of Research Integrity and Ethics on +61 7 4631 2214 or email researchintegrity@usq.edu.au, if you have any concern or complaint about the ethical conduct of this project.	☐Yes / ☐No
• Are over 18 years of age.	☐Yes / ☐No
• Understand that any data collected may be used in future research activities.	☐Yes / ☐No
• Agree to participate in the project.	☐Yes / ☐No

Page **1** of **2**



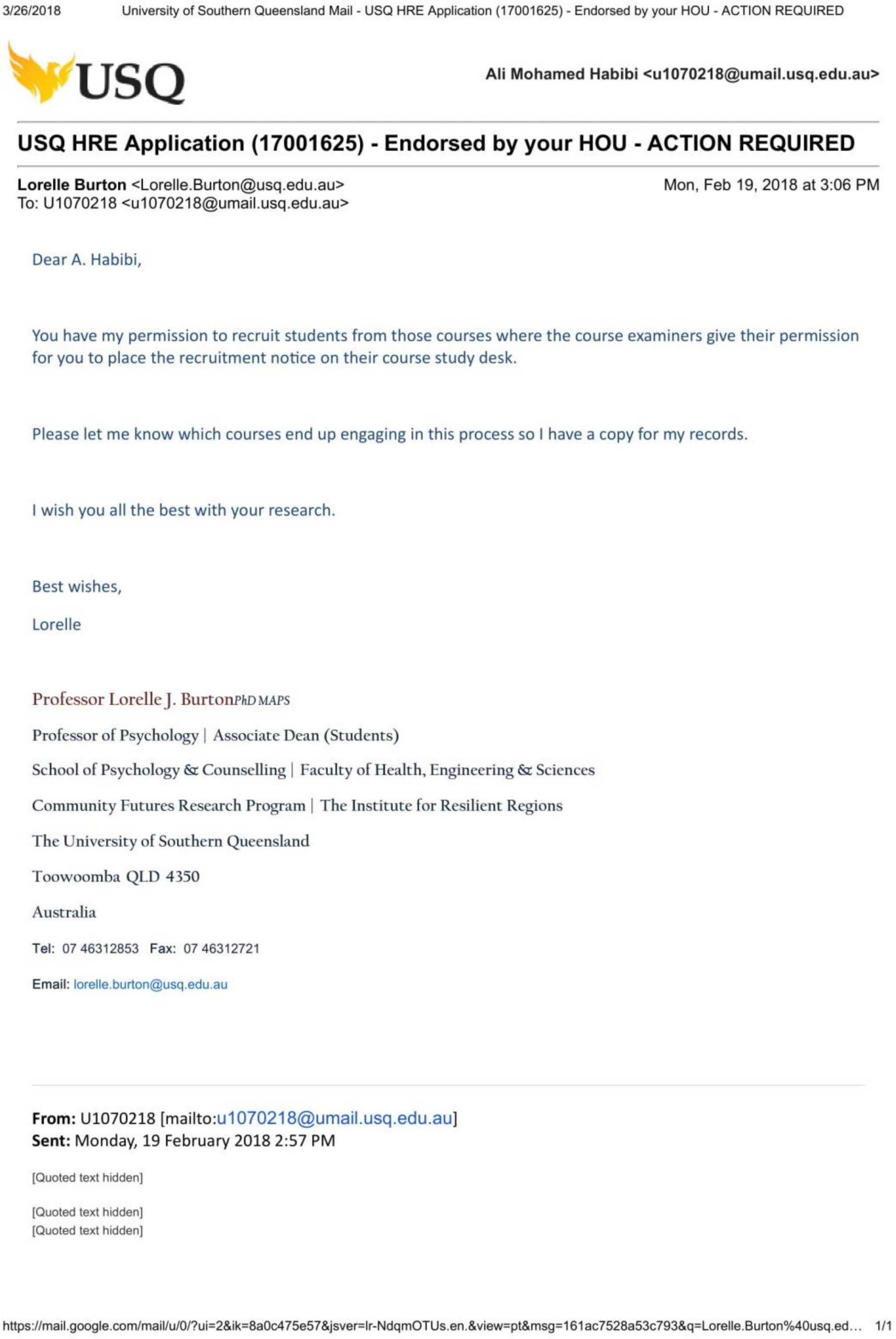
Participant Name	
Participant Signature	
Date	

☐ Please tick this box and provide your email address below if you wish to receive a summary of the research results.

Email:___________________________________

Please return this sheet to a Research Team member prior to undertaking the interview.

Appendix K: Permission to Recruit Students



3/26/2018 University of Southern Queensland Mail - USQ HRE Application (17001625) - Endorsed by your HOU - ACTION REQUIRED

USQ

Ali Mohamed Habibi <u1070218@umail.usq.edu.au>

USQ HRE Application (17001625) - Endorsed by your HOU - ACTION REQUIRED

Lorelle Burton <Lorelle.Burton@usq.edu.au> Mon, Feb 19, 2018 at 3:06 PM
To: U1070218 <u1070218@umail.usq.edu.au>

Dear A. Habibi,

You have my permission to recruit students from those courses where the course examiners give their permission for you to place the recruitment notice on their course study desk.

Please let me know which courses end up engaging in this process so I have a copy for my records.

I wish you all the best with your research.

Best wishes,

Lorelle

Professor Lorelle J. Burton*PhD MAPS*

Professor of Psychology | Associate Dean (Students)

School of Psychology & Counselling | Faculty of Health, Engineering & Sciences

Community Futures Research Program | The Institute for Resilient Regions

The University of Southern Queensland

Toowoomba QLD 4350

Australia

Tel: 07 46312853 **Fax:** 07 46312721

Email: lorelle.burton@usq.edu.au

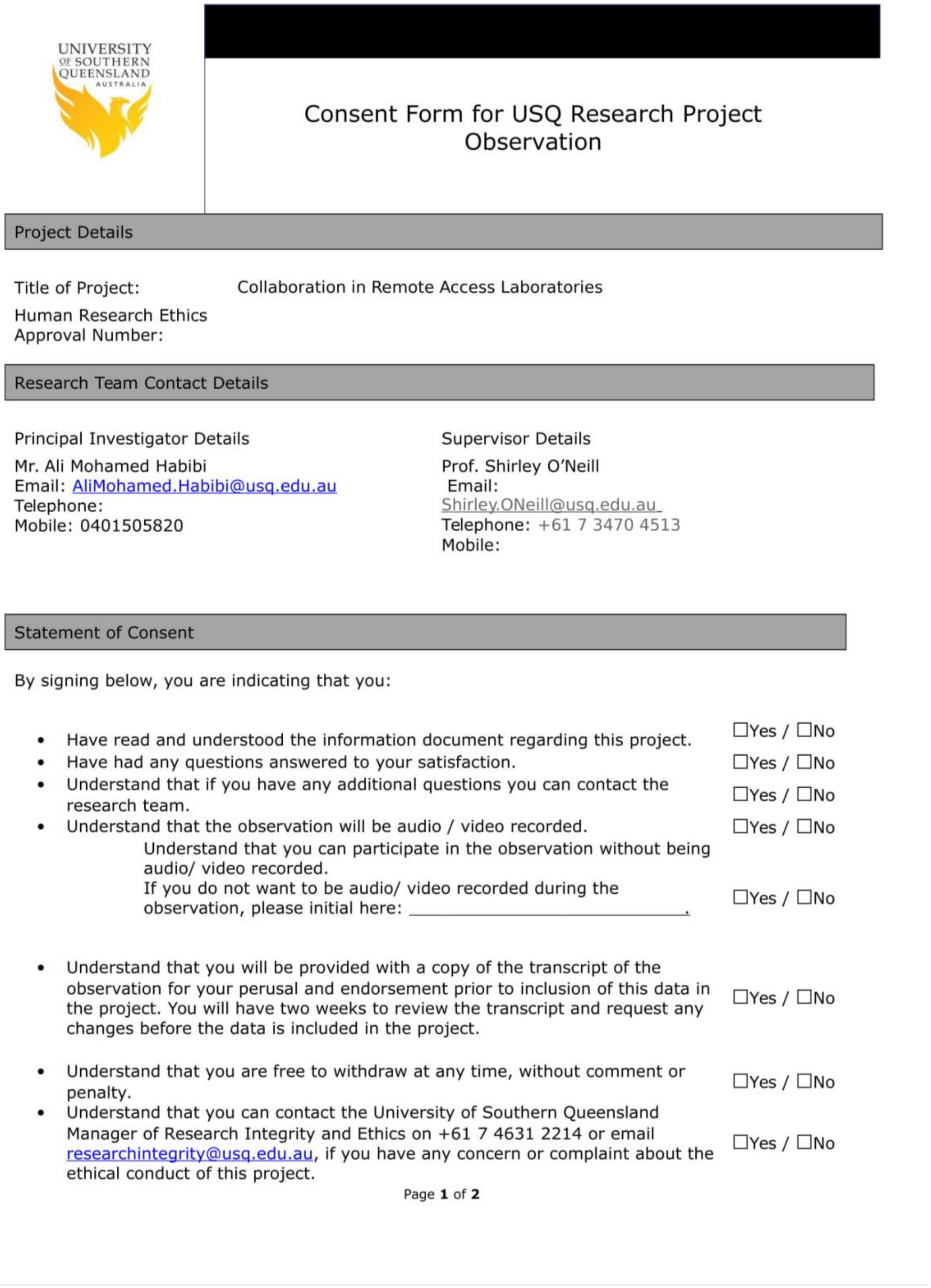
From: U1070218 [mailto:u1070218@umail.usq.edu.au]
Sent: Monday, 19 February 2018 2:57 PM

[Quoted text hidden]

[Quoted text hidden]
[Quoted text hidden]

https://mail.google.com/mail/u/0/?ui=2&ik=8a0c475e57&jsver=lr-NdqmOTUs.en.&view=pt&msg=161ac7528a53c793&q=Lorelle.Burton%40usq.ed… 1/1

Appendix L: Observation Consent Form



UNIVERSITY OF SOUTHERN QUEENSLAND
AUSTRALIA

Consent Form for USQ Research Project Observation

Project Details

Title of Project: Collaboration in Remote Access Laboratories

Human Research Ethics Approval Number:

Research Team Contact Details

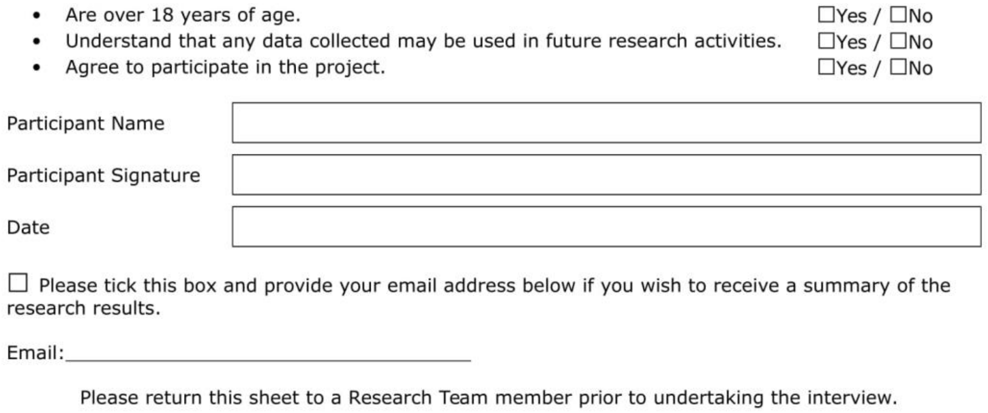
Principal Investigator Details	Supervisor Details
Mr. Ali Mohamed Habibi	Prof. Shirley O'Neill
Email: AliMohamed.Habibi@usq.edu.au	Email: Shirley.ONeill@usq.edu.au
Telephone:	Telephone: +61 7 3470 4513
Mobile: 0401505820	Mobile:

Statement of Consent

By signing below, you are indicating that you:

- Have read and understood the information document regarding this project. ☐Yes / ☐No
- Have had any questions answered to your satisfaction. ☐Yes / ☐No
- Understand that if you have any additional questions you can contact the research team. ☐Yes / ☐No
- Understand that the observation will be audio / video recorded. ☐Yes / ☐No
  Understand that you can participate in the observation without being audio/ video recorded.
  If you do not want to be audio/ video recorded during the observation, please initial here: ______________________________. ☐Yes / ☐No
- Understand that you will be provided with a copy of the transcript of the observation for your perusal and endorsement prior to inclusion of this data in the project. You will have two weeks to review the transcript and request any changes before the data is included in the project. ☐Yes / ☐No
- Understand that you are free to withdraw at any time, without comment or penalty. ☐Yes / ☐No
- Understand that you can contact the University of Southern Queensland Manager of Research Integrity and Ethics on +61 7 4631 2214 or email researchintegrity@usq.edu.au, if you have any concern or complaint about the ethical conduct of this project. ☐Yes / ☐No

Page **1** of **2**



- Are over 18 years of age. ☐Yes / ☐No
- Understand that any data collected may be used in future research activities. ☐Yes / ☐No
- Agree to participate in the project. ☐Yes / ☐No

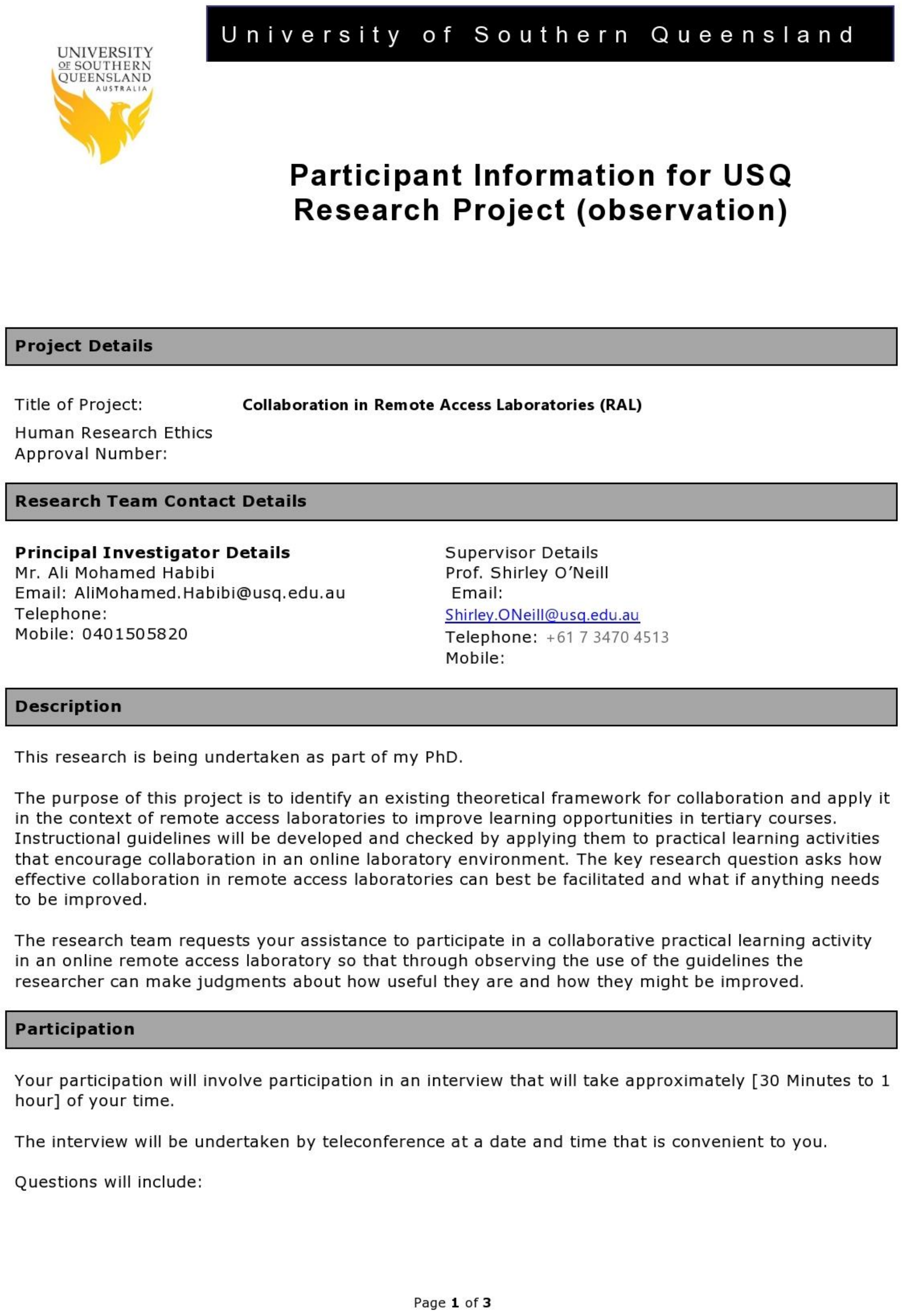
Participant Name	
Participant Signature	
Date	

☐ Please tick this box and provide your email address below if you wish to receive a summary of the research results.

Email:____________________________________

Please return this sheet to a Research Team member prior to undertaking the interview.

Appendix M: Observation Information Sheet



University of Southern Queensland

Participant Information for USQ Research Project (observation)

Project Details

Title of Project: **Collaboration in Remote Access Laboratories (RAL)**

Human Research Ethics Approval Number:

Research Team Contact Details

Principal Investigator Details
Mr. Ali Mohamed Habibi
Email: AliMohamed.Habibi@usq.edu.au
Telephone:
Mobile: 0401505820

Supervisor Details
Prof. Shirley O'Neill
Email:
Shirley.ONeill@usq.edu.au
Telephone: +61 7 3470 4513
Mobile:

Description

This research is being undertaken as part of my PhD.

The purpose of this project is to identify an existing theoretical framework for collaboration and apply it in the context of remote access laboratories to improve learning opportunities in tertiary courses. Instructional guidelines will be developed and checked by applying them to practical learning activities that encourage collaboration in an online laboratory environment. The key research question asks how effective collaboration in remote access laboratories can best be facilitated and what if anything needs to be improved.

The research team requests your assistance to participate in a collaborative practical learning activity in an online remote access laboratory so that through observing the use of the guidelines the researcher can make judgments about how useful they are and how they might be improved.

Participation

Your participation will involve participation in an interview that will take approximately [30 Minutes to 1 hour] of your time.

The interview will be undertaken by teleconference at a date and time that is convenient to you.

Questions will include:

The interview will be undertaken by teleconference at a date and time that is convenient to you.

Questions will include

- Does the success of one participant will benefit other participants?
- Is individual or public performance required?
- How percentage is the participation engages?
- What percent are interacting at same time?
- How did you find working collaboratively to do the task?
- What were the benefits of collaborating?
- How could carrying out this practicum be improved?
- What is your attitude towards collaborative activity?
- Why is it important to work together on a collaborative learning team?
- What would help you work better as a team?
- What could peers do to help you with activity?
- What helps to get you involved in collaboration activity?
- Does working in a collaborative activity team help get you involved in your learning? If so, why do you think that is?
- How do you participate in your collaborative activity groups?

The interview will be audio / video recorded.

Your participation in this project is entirely voluntary. If you do not wish to take part you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. You may also request that any data collected about you be destroyed. If you do wish to withdraw from this project or withdraw data collected about you, please contact the Research Team (contact details at the top of this form).

Your decision whether you take part, do not take part, or to take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland or External organisation name.

Expected Benefits

It is expected that this project will directly benefit you because the main aim of this research is to establish an instructional framework and providing recommendations for the facilitation of online collaboration via remote access laboratories. The research will focus specifically on a structural framework for collaboration between remote access laboratories. However, it could be extended to collaboration online generally. Laboratory teaching can be improved through collaboration in an online laboratory and so can enhance learning outcomes. Online collaboration will be a part of future teaching in an online environment. Collaboration in RAL can play a key role in positively influencing the outcomes of participant learning. Also it is designed to encourage participants to undertake speed of interaction; experience clear articulation of expectations and timeliness of feedback; engage participants to share their ideas by interacting, and have the opportunity to discuss results and so enhance outcomes.

Risks

Choose one of the following options (refer to responses provided in 1A.9 – 1A.13 of the ethics application:

There are no anticipated risks beyond normal day-to-day living associated with your participation in this project.

Privacy and Confidentiality

All comments and responses will be treated confidentially unless required by law.

For audio or video recording Information should also be provided to inform a participant:

- If the interviews will be audio and/ or video recorded.
- If they will be provided with a copy of the interview transcript for review and endorsement prior to inclusion in the project data
- The expected time frame they will be given to review and request any changes to the transcript before the data is included in the project (i.e. two weeks).
- If the recording will be used for any other purpose (i.e. as a teaching/ instructional tool)
- Who will have access to the recording, including who may be involved in the transcribing of the recording (if this will be conducted by a person or persons outside of those listed as investigators for this project)?
- Whether it is possible to participate in the project without being recorded.

Include a statement about how data collected may be used in future research.*(please note in accordance with 2.5.2 of the "Australian Code for the Responsible Conduct of Research", research data should be made available for use by other researchers unless this is prevented by ethical, privacy or confidentiality matters).*

Include details about how participants will be provided with or how they can access the project summary of results (*in accordance with 4.4.3 of the Australian Code for the Responsible Conduct of Research, researchers must where feasible, must also provide research participants with an appropriate summary of the research results*).

If the project is funded by an external third party, you will need to inform participants of this. No statement is required if the project is self (or University) funded.

Any data collected as a part of this project will be stored securely as per University of Southern Queensland's Research Data Management policy.

Consent to Participate

We would like to ask you to sign a written consent form (enclosed) to confirm your agreement to participate in this project. Please return your signed consent form to a member of the Research Team prior to participating in your interview.

Questions or Further Information about the Project

Please refer to the Research Team Contact Details at the top of the form to have any questions answered or to request further information about this project.

Concerns or Complaints Regarding the Conduct of the Project

If you have any concerns or complaints about the ethical conduct of the project you may contact the University of Southern Queensland Manager of Research Integrity and Ethics on +61 7 4631 2214 or email researchintegrity@usq.edu.au. The Manager of Research Integrity and Ethics is not connected with the research project and can facilitate a resolution to your concern in an unbiased manner.

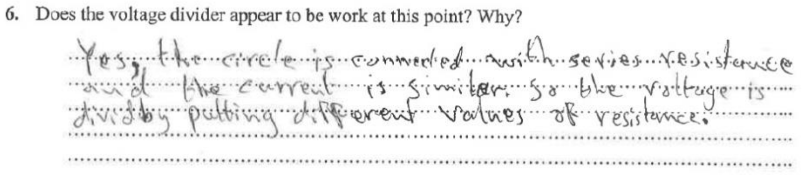
Thank you for taking the time to help with this research project. Please keep this sheet for your information.

Appendix N: Student Response Task Sheet

Student response on task

"Does the voltage divider appear to be work at this point? Why?"

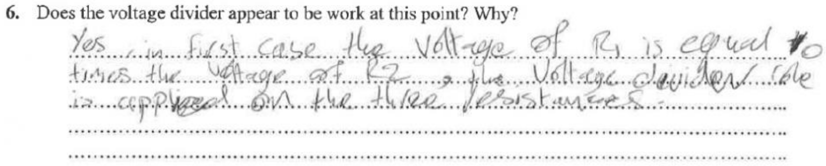
RO4



6. Does the voltage divider appear to be work at this point? Why?

Yes, the circle is connected with series resistence and the current is similar. so the voltage is dividby putting different values of resistance.

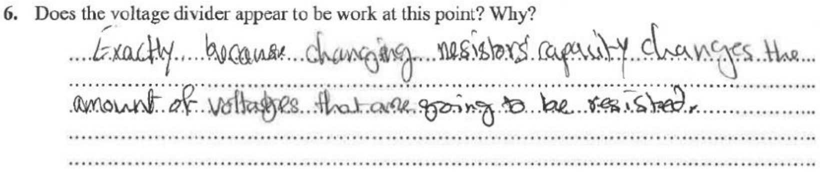
Y01



6. Does the voltage divider appear to be work at this point? Why?

Yes , in first case the voltage of R_1 is equal to times the voltage of R2 , the Voltage divider role is applied on the three resistances .

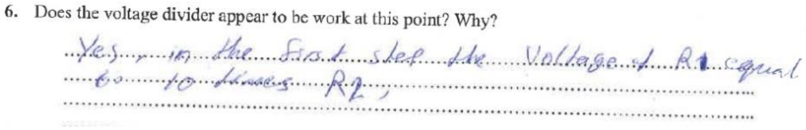
O010



6. Does the voltage divider appear to be work at this point? Why?

Exactly because changing resistors capacity changes the amount of voltages that are going to be resisted.

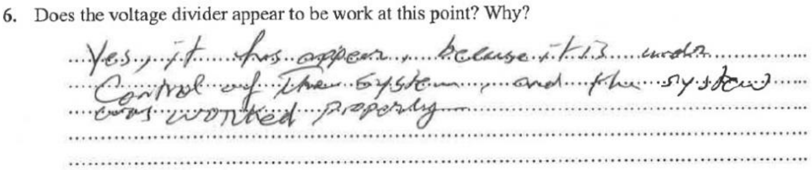
M07



6. Does the voltage divider appear to be work at this point? Why?

Yes , in the first step the Voltage of R1 equal to to times R2 ,

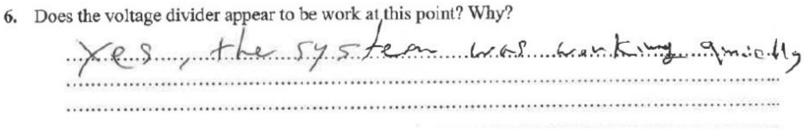
S09



6. Does the voltage divider appear to be work at this point? Why?

Yes, it has appear, because it is under Control of The System, and the system was worked properly

N06



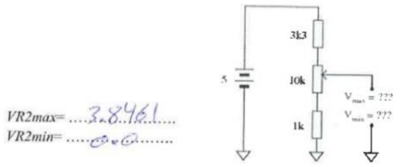
6. Does the voltage divider appear to be work at this point? Why?

Yes, the system was working quickly

Next step the students have asked to calculate both the maximum and the minimum amount of voltage obtainable from this potentiometer circuit (as measured between the wiper and ground):

This is a snapshot from one student of calculation from the student task sheet.

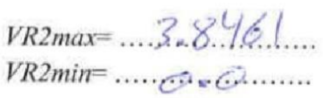
M07 :



VR2max= ....3.8461....

VR2min= .....0.0.......

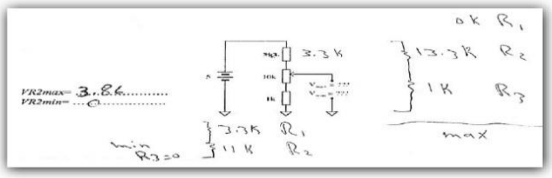
N06:



VR2max= ....3.8461....

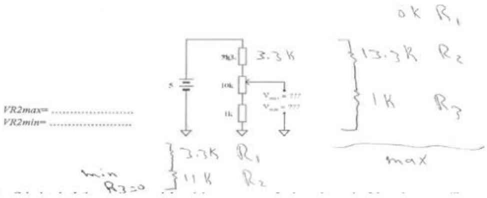
VR2min= .....0.0.......

O010:



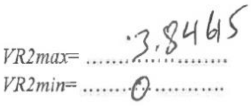
VR2max= 3.86..........
VR2min= ...0...............

R05:



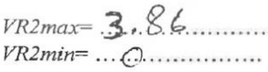
VR2max= ....
VR2min= ....

S09:



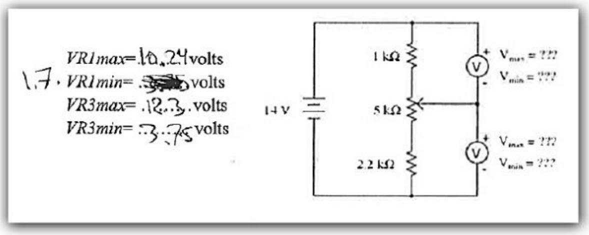
VR2max= ....3.8465........
VR2min= ....0..........

Y01



VR2max= 3.86..........
VR2min= ...0...............

Next step student calculates both the maximum and the minimum amount of voltage that each of the voltmeters will register, at each of the potentiometer's extreme positions:



VR1max=10.24volts

1.7· *VR1min*= [illegible] volts

VR3max= 12.3 volts

VR3min= 3.75 volts

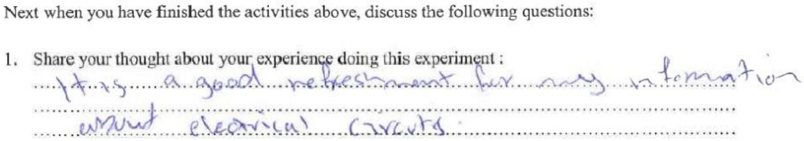
Analysis

After the student finish the task start to discus and analysis fires question about ,

Share your thought about your experience doing this experiment:

M07: We can start the analysis of some of the group share your thought about this experiment. So, what do you think?

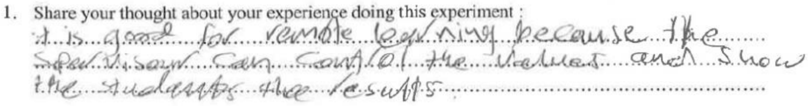
R04



Next when you have finished the activities above, discuss the following questions:

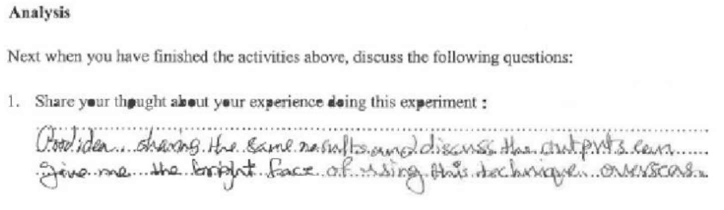
1. Share your thought about your experience doing this experiment :
It is a good refreshment for my information
about electrical circuits.

Y01



1. Share your thought about your experience doing this experiment :
it is good for remote learning because the
supervisor can control the values and show
the students the results.

O010



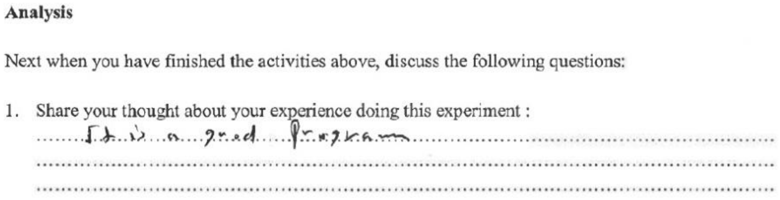
Analysis

Next when you have finished the activities above, discuss the following questions:

1. Share your thought about your experience doing this experiment :

Good idea... sharing the same results and discuss the outputs can...
give me the bright face of using this technique... overseas.

N06



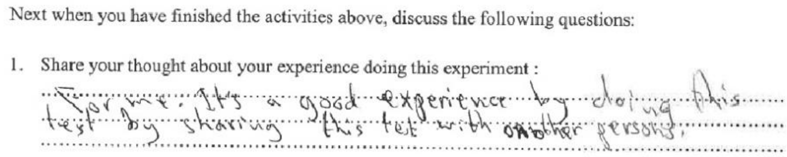
Analysis

Next when you have finished the activities above, discuss the following questions:

1. Share your thought about your experience doing this experiment :

It is a good Program

R05

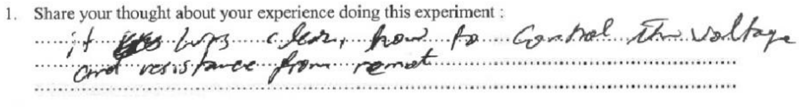


Next when you have finished the activities above, discuss the following questions:

1. Share your thought about your experience doing this experiment :

For me: It's a good experience by doing this
test by sharing this tet with another persons;

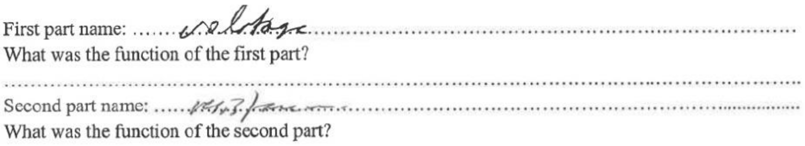
S09



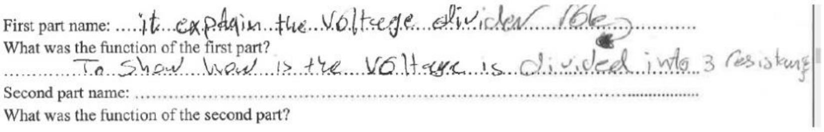
1. Share your thought about your experience doing this experiment :

it ~~[illegible]~~ was clear, how to Control the voltage
and resistance from remot

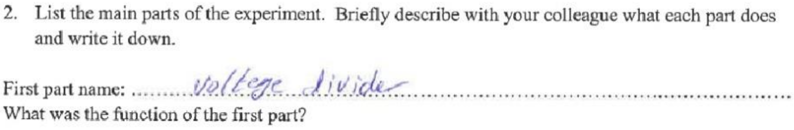
S09


First part name: ……voltage……………………………………………
What was the function of the first part?
……………………………………………………………………
Second part name: ……[illegible]……………………………………
What was the function of the second part?

Y01

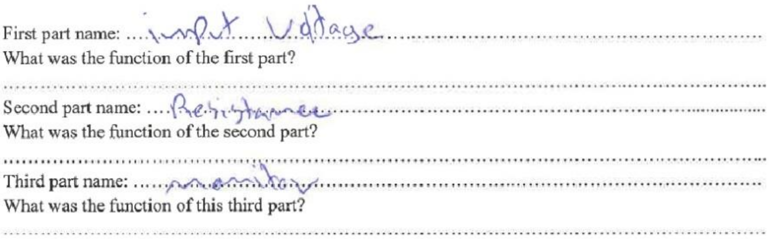

First part name: ….it explain the Voltege divider 16k……………
What was the function of the first part?
……To show how is the Voltage is divided into 3 resistors
Second part name: ……………………………………………………
What was the function of the second part?

M07

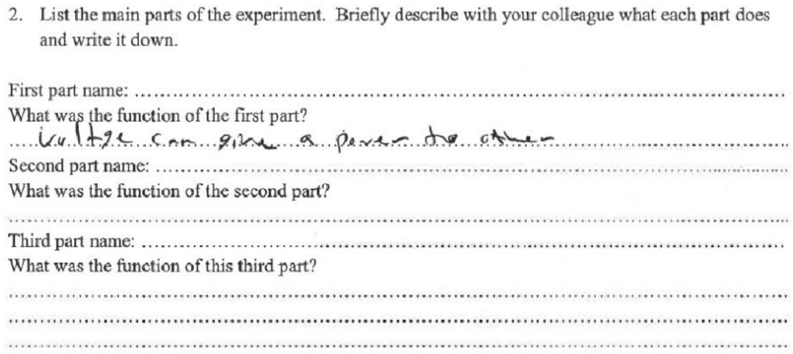

2. List the main parts of the experiment. Briefly describe with your colleague what each part does and write it down.

First part name: ……voltege divide……………………………………
What was the function of the first part?

R04


First part name: …input Voltage……………………………………
What was the function of the first part?
……………………………………………………………………
Second part name: …Resistance……………………………………
What was the function of the second part?
……………………………………………………………………
Third part name: ……monitor………………………………………
What was the function of this third part?
……………………………………………………………………

N06



2. List the main parts of the experiment. Briefly describe with your colleague what each part does and write it down.

First part name: ……………………………………………………………………………

What was the function of the first part?

……vultge can give a pover to other……………………………………

Second part name: ……………………………………………………………………………

What was the function of the second part?

……………………………………………………………………………………………………

Third part name: ……………………………………………………………………………

What was the function of this third part?

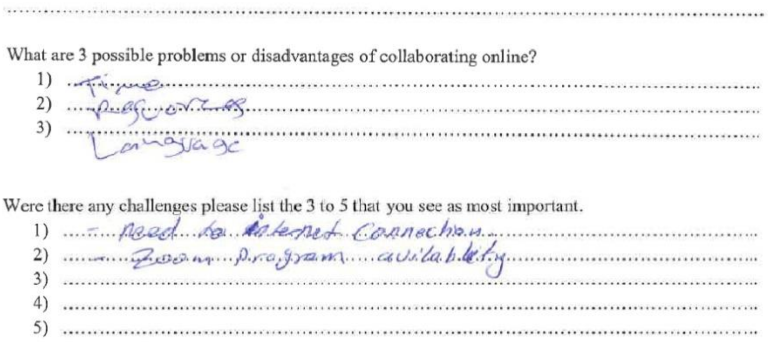
……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

What are the 3 possible problems or disadvantages of collaborating online?

R04

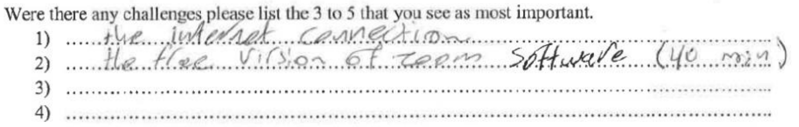


What are 3 possible problems or disadvantages of collaborating online?

1) ……Time……………………………………………………………………
2) ……passwords……………………………………………………………
3) ……Language……………………………………………………………

Were there any challenges please list the 3 to 5 that you see as most important.

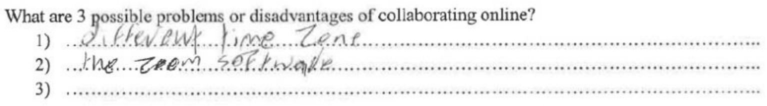
1) ……need to internet connection……………………………………
2) ……Zoom program avilablity…………………………………………
3) ……………………………………………………………………………
4) ……………………………………………………………………………
5) ……………………………………………………………………………



Were there any challenges please list the 3 to 5 that you see as most important.

1) ……the internet connection……………………………………………
2) ……the free virsion of team software (40 min)
3) ……………………………………………………………………………
4) ……………………………………………………………………………

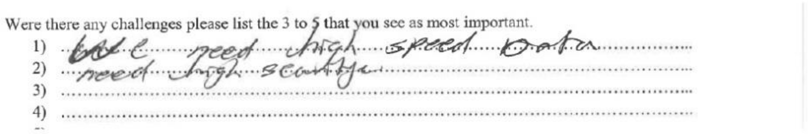
Y01



What are 3 possible problems or disadvantages of collaborating online?

1) different time Zone
2) the zoom software
3)

S09



Were there any challenges please list the 3 to 5 that you see as most important.

1) ~~we~~ e need high speed Data
2) need high security
3)
4)