‘An investigation of the effectiveness of Reusable Learning Objects as a blended learning tool in an undergraduate engineering design module’.

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Abstract

Blended learning is an emerging trend across many educational settings, adopting the purposeful integration of traditional face-to-face and online teaching to establish an engaging learning experience for the students. Digital technologies and varied pedagogical strategies in a new blend of approaches to learning and teaching are enhancing the learning experience. Blended learning provides an ideal platform for the implementation of Reusable Learning Objects (RLO's) as a pedagogical tool to support classroom instruction. This study investigated the effectiveness of RLO's as a blended learning tool in undergraduate engineering design modules in IT Sligo. A quasi experimental study was employed, involving 38 students from the 2014/2015 academic year, as the control group and 41 students from the 2015/2016 academic year, as the experimental group. A mixed methods approach, combining aspects of quantitative and qualitative data was employed to evaluate this intervention, in terms of student academic achievement and student perceptions of the blended approach. There was no statistical difference in the mean of the overall grades between both groups, across both modules. Further analysis revealed sufficient statistical evidence to suggest that the blended learning approach had a significant impact on the students' end of term exam grades in the module Design 102, supported by an effect size of 0.37 and a significant positive relationship, $r = 0.44$, between the students' RLO's usage and end of term exam grades in Design 102. Student perceptions of the blended learning approach were very positive; consistent with the literature, with the RLO's viewed as a means of reinforcing their understanding of material covered in class. These design modules may be more suited to the implementation of RLO's, therefore, a similar blended approach should be employed across other modules and compare the findings.

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Section One: Rationale and Introduction

1.1. Overview

The use of information technology has brought changes to the face of education, creating new opportunities for Higher Education Institutes (HEI's) and enhancing the learning experience for both students and teachers. The National Forum for the enhancement of teaching and learning in higher education note that over the last two decades our Institutions have acted alone in responding to the change in the digital culture we have experienced. Kinchin (2012) also argues that the lack of effective communication between stakeholders in the past has hindered the progress that has been made to integrate new technologies into teaching. While IT Sligo and many other institutes and universities have adopted the use of technology with a view of changing the learning paradigm, (O'Rourke *et al.* 2015) argue that the model of teaching and learning has not changed much over the last decade. Garrison and Vaughan (2008) also highlighted in their study that higher education institutes need to deliver on their promises of delivering learning experiences that cater for the needs of the cohort of students in the twenty-first century. Rapid advancements in Information and Communications Technology (ICT), budget constraints and calls for higher levels of quality of education require HEI's to transform their approach to teaching and learning.

Blended learning has the potential to address these issues in both full time and online learning and we need to act on this to ensure we are not left behind as other parts of the world are garnering the benefits of technology (McAleese 2014). We should move on from the old way of doing things and make use of the emerging technologies that can have a meaningful impact on both the learning and the teaching experience. The report of the European High Level Working Group on the Modernisation of Higher Education (2014) comment on how new technologies and new pedagogies go hand in hand and how teachers should introduce digital innovations in their pedagogical approaches in response to these challenges. The introduction of Reusable Learning Objects (RLO's) as a blended learning tool could be seen as one such digital innovation and the researcher feels that the findings from this study will contribute to the present research into the domain of blended learning, by examining the effect that RLO's had in enhancing student learning in an undergraduate engineering module.

1.2. Rationale

It is felt that by adopting a form of blended learning approach, using RLO's, in first year engineering undergraduate modules in Computer Aided Design (CAD), will allow students to take control of their own learning and construct understanding at their own pace. These design modules aim to introduce students to the engineering design process and provide them with the skills required to produce models and drawings of individual engineering parts using a 3D CAD system known as SolidWorks. Having been involved with these modules and from discussions with colleagues, there was a consensus that there was a requirement for this type of approach, to enhance the learning environment and support the diversity that is evident in this particular module. On average, around 50 to 60 per cent of the students have had no previous experience of using a form of CAD software. Student diversity, students' prior knowledge of design and the creative nature of CAD are common issues that make it difficult to facilitate learning. O'Connor (2015) argues that using a blended approach in the design and delivery of learning materials helps address diverse learning needs, enhancing the students' learning experience.

The use of video technology for supplementing traditional lectures is increasing in higher education (Haylo and Le 2013) and the fast pace and rich content of engineering courses make this a suitable environment to use these technologies to help emphasis difficult concepts (Dutil *et al*. 2015). In this study, students had access to a series of RLO's, to further strengthen their knowledge and skills of the design process. These RLO's were made available through a Virtual Learning Environment (VLE) known as Moodle. The RLO's, in the form of video tutorials developed by the researcher using a video platform known as Panopto, are self-paced, providing the learner with a means to be flexible in how they access the material. The RLO's allow the learner to familiarise themselves with new material and concepts, which will reduce their cognitive load during class time, allowing deep learning to occur, a view supported by (Delialioglu and Yildirim 2008; Seery and Donnelly 2012). Although there is plethora of studies on the effects of blended learning, the literature on blended learning in engineering education is limited, although Francis and Shannon (2013, p.361) would argue that blended learning is "embedded within engineering curricula", which warrants the need for further research into this area.

This research investigated the use of RLO's as a blended learning tool, a means of incorporating simple low-risk tools to support face-to-face learning in the first step to a broader adoption of blended learning (Francis and Shannon 2013). Ginns and Ellis (2009) argue that practical studies are required to evaluate how these tools can contribute to student learning, especially when they are used to complement face-to-face teaching methods. There are no apparent studies that have examined the use of RLO's as a blended learning tool in teaching CAD; therefore, this study fills this gap in the literature.

1.3. Introduction to the research design

This research has conducted a quasi-experimental methodology to determine if a blended learning approach can enhance student learning in an undergraduate engineering module. The research study involved students studying engineering design modules in the 2014/2015 academic year and the 2015/2016 academic year. This comparative cross-sectional study, where all aspects of the educational experience are identical except from the technology used (Kirkwood and Price 2013, p.538), compared the outcome of a blended learning versus a traditional face-to-face teaching approach. Students from the 2015/2016 academic year adopted a blended learning approach by accessing a series of RLO's made available through a VLE, over the duration of these modules. The previous cohorts of students from the 2014/2015 academic year were taught using traditional face-to-face teaching approaches only. The study was administered through design modules titled 'Design 101/102', delivered to first year undergraduate mechanical engineering students in the Institute of Technology Sligo.

The research used a mixed method approach using quantitative data in the form of *t*-tests, effect sizes and correlation analysis and qualitative data in the form of semi-structured interviews to reinforce the findings of the study, drawing out common perceptions according to the themes. The research proposal was given approval by the Research Ethics Committee's (REC) prior to the commencement of data collection.

1.4. Organisation of the Thesis

Section 1 provides a detailed introduction to the study, rationale of the study, introduction to the research design and the thesis structure.

Section 2 reviews and critiques the available literature surrounding blended learning with the main focus on its benefits and effectiveness in higher education from the students' perspective. This chapter also examines and critiques the concept of RLO's as a blended learning tool, highlighting gaps in the literature in relation to evaluating the student's perceptions of using RLO's in a blended environment.

Section 3 provides an overview of the research methodology used in the study, a description of the site selection and research participants, the researcher's philosophy and a detailed overview of the research techniques and procedures, including the data collection materials and analysis. The research findings, with analysis of the study results, drawing from associated literature is then presented, concluding with an overview of the findings.

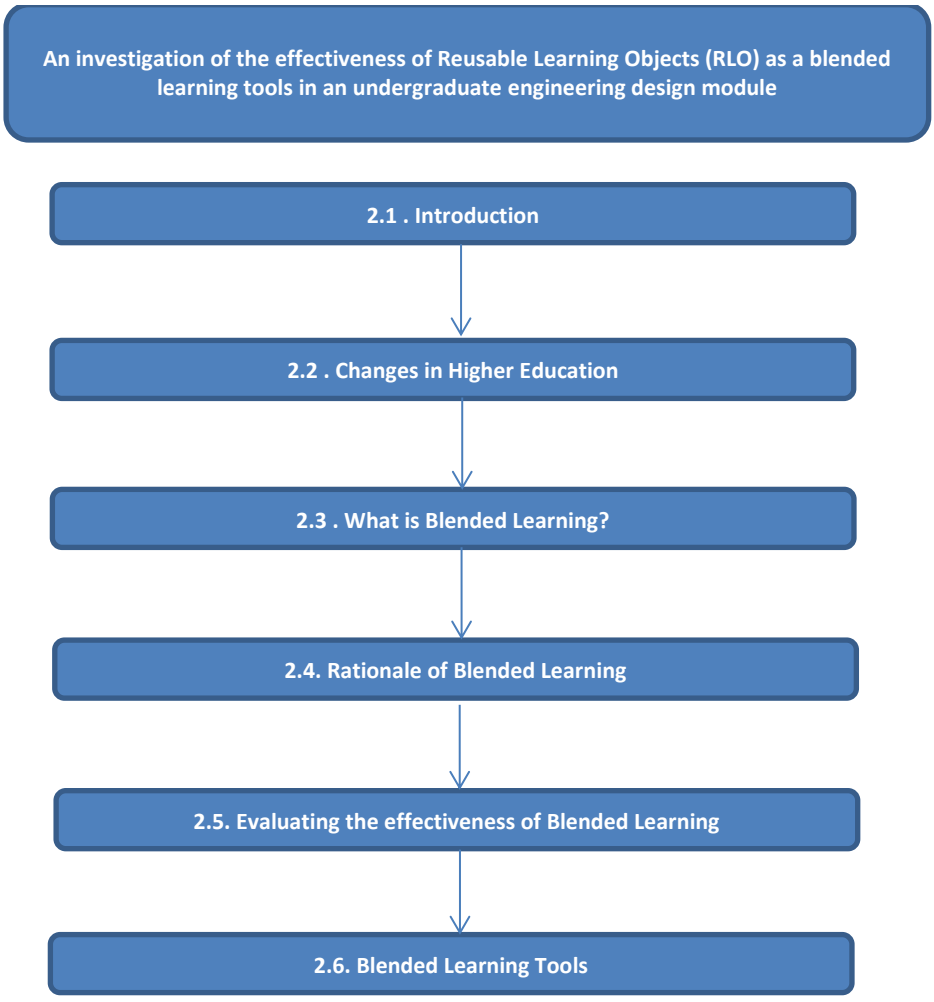
Section 4 summarizes the conclusion of the research findings. The limitations of the study are discussed and recommendations for future research highlighted.

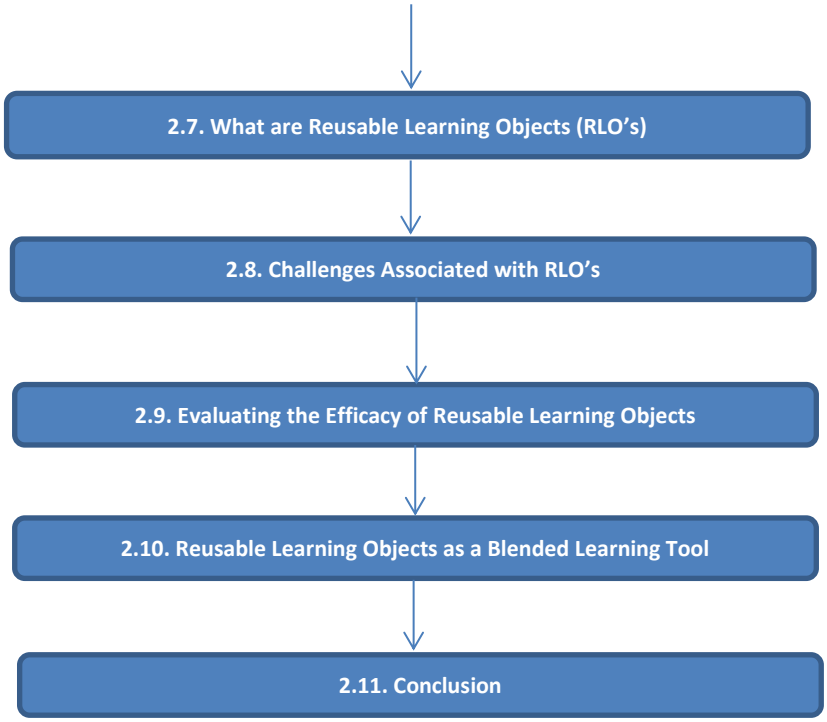
Section Two: Literature Review and Critique

2.1. Introduction

This section provides an extensive literature review and synthesis in the field of blended learning, in relation to its definition, rationale, opportunities, effectiveness and challenges, in the context of higher education, to support the research aim of this study. The research covers relevant and recent literature, that is not confined to "one research methodology, one set of journals, or one geographic region", as recommended by Webster and Watson (2002, p.15). In addition, a review of the previous research, frameworks and theories related to the effectiveness of RLO's is presented, with the main emphasis on the learner's experience of using these learning resources. The structure of the literature review is shown in Figure 2.1.

Figure 2-1: Structure of the Literature Review





2.2. Changes in Higher Education

Higher education institutions are spending a considerable amount of time and research responding to the changes in digital culture, in relation to its potential for institutions, practitioners and students alike. They are striving to provide suitable learning experiences to address the ever changing educational needs of a new generation of students that are coming through the education system. These changes are universal and no more so than in Irish higher education, which according to Hunt (2011) is now at a point of transition. The number of students entering the higher education system is increasing, the profile of the students is always changing and there is a steady rise in the amount of non-traditional learners. To be in a position to cater for these changes, Irish higher education needs to be innovative in the manner in which they provide opportunities for the diverse cohort of students coming through the system.

2.2.1. Using Technology to enhance Higher Education

Technology has changed how students can access education, allowing them to take advantage of the quality and effectiveness that higher education has to offer. The National Strategy for Higher Education to 2030 (Hunt 2011) clearly state the role that technology should play in assisting the learning experience. The report highlights how technology supported learning has developed over the last decade with the introduction of VLE's such as Blackboard and Moodle. A recent study by O'Rourke *et al.* (2015), indicate high levels of VLE usage among

academics in Irish higher education. More recently academics have adopted the use of VLE's to support their existing practices in their face-to face delivery, enabling new forms of learning that are unconstrained by time or location, enhancing the student learning experience. The widespread availability of VLE's provides educational institutions with a suitable platform to adopt blended learning, to enhance educational delivery (Obadara 2014) and provide a flexible learning experience. So, what is this new learning experience and is there any evidence that it is effective?

2.3. What is Blended Learning?

The term blended learning has been discussed considerably over the last decade, with different viewpoints among practitioner's and researchers of what blended learning is defined as (Bonk and Graham 2004; Singh 2004; Stubbs *et al.* 2006). There appears to be no single accepted definition, however there is a general consensus that blended learning is a combination of face-to-face learning with some form of technology based learning. It could be argued that different individuals may have their own interpretation of what blended learning is, allowing them to negotiate their own meaning.

Oliver and Trigwell (2005) look at it through a different lens. They conducted an in-depth study in which they reviewed many different definitions of blended learning and they argue that with this lack of clarity, anything could be seen as blended learning. They argue that blended learning should be analysed from the learners perspective and experience of been involved in it, moving away from the blended environment been viewed from a teachers perspective. Garrison and Vaughan (2007, p.5) portray blended learning in a simplified manner in which they view it as "the thoughtful fusion of face-to-face and online learning experiences". Their view of blended learning is similar to the work of Graham (2006). Graham's definition and explanations are widely referenced and support the views that blended learning has a natural place in higher education contexts.

The researcher feels that the work of Graham helps clarify where this study lies in relation to the adoption of a blended learning approach. Graham (2006) catagorised the global practices of blended learning into four main levels, activity level, course level, program level, and institutional level. This study falls into the activity level, generally determined by the course lecturer, in which a form of enhancing blend will be used, providing online supplementary resources to support traditional teaching methods.

2.4. Rationale for Blended learning

HEI's are recognising the need to respond to the fast and radically changing environment. Advancements in technology, changing demographics and the ever shifting expectations of suitable learning environments require HEI's to examine their teaching and learning strategies. Garrison and Vaughan (2008, p. 153) believe that blended learning provides an opportunity to address these pedagogical concerns and also enhance "the reputation of institutions of higher education as innovative and quality learning institutions".

Adopting a blended learning approach has the potential to expand, improve and transform face-to-face learning (Donnelly 2010), changing the teaching paradigm, shifting the emphasis from teaching to learning (Lopez *et al.* 2011). According to Klein *et al.* (2006), a blended learning environment encourages self-directed learning, requiring the students to take more responsibility for their learning. Furthermore, Cortizo *et al.* (2010) are of the opinion that blended learning provides an opportunity for students to experience the integration of innovative technological advances that are available online, with the important traits that traditional learning has to offer, combining the best of both worlds. Graham and Robinson (2007) suggest that as well as improving pedagogy, blended learning will allow for increased access and flexibility for the cohort of non-traditional students that try and balance work life and university life, by reducing the amount of face-to-face contact hours required.

Supported by further important literature in this area, the researcher concludes that blended learning has the advantages of pedagogical richness (Graham 2006), extending learning beyond the classroom (Jokinen and Mikkonen 2013; Smyth *et al*. 2012), decreased retention rates (Hughes 2007; Lopez *et al*. 2011; Wall and Ahmed 2008), greater flexibility (Poon 2012), increased cost-effectiveness (Harding *et al.* 2005; Vernadakis *et al*. 2011) and greater accommodation for a diverse cohort of learners (Sharpe *et al*. 2006).

2.5. Evaluating the Effectiveness of Blended Learning

A wide range of studies have been published that compare both blended learning and online environments to a face-to-face learning environment (Garrison and Kanuka 2004; Ginns and Ellis 2007; Singh 2003). Evaluations of the effectiveness (Bonk and Graham 2012; So and Brush 2008), design (Stubbs *et al.* 2006), implementation (Davis and Fill 2007) and challenges (Dalsgaard and Godsk 2007; Kaur 2013; Parrish 2004) of blended learning dominate the research to date.

Regardless of some of the comparisons made by researchers and developers in this domain, recent literature into blended learning agrees that student experience (Ginns and Ellis 2009; Hughes 2007; Koch *et al*. 2010; Smyth *et al.2010*) and satisfaction (So and Brush 2008; Wu *et al.* 2010) is a baseline requirement for successful implementation and is widely considered as a necessity in evaluating the quality of blended learning. A growing body of research on student evaluations of the blended learning approach (Arbaugh *et al.* 2009; Harnisch and Taylor-Murison 2012; Lopez *et al.* 2011; Poon 2012; Waha and Davis 2014; Wu *et al.* 2010) highlight the benefits of adopting this approach. Poon (2012) suggests that blended learning can successfully improve students' experience, when a range of delivery methods are adopted, which in turn can improve student achievement. In addition, Lopez *et al.* (2011) study shows that blended learning has a positive effect in improving exam marks and in improving student retention, a similar finding to (Hughes 2007; Wankel and Blessinger 2013). These are significant findings, in an era where third level institutions are looking to improve their student retention rates.

In addition to the students' perceptions of these innovative approaches, the evaluation of students' academic achievements in comparison to traditional approaches are common in recent studies (Castano *et al*. 2014; Cosgrove and Olitsky 2015; LaMeres and Plumb 2014; Mersal and Mersal 2014). These types of studies are important for evaluating if a blended approach has a negative or positive effect on student learning and they rely on effective statistical analysis to guide the research, often in the form of statistical tests of significance. Researchers need to be cautious in using statistical significance (Cohen *et al.* 2011) and some researchers argue (Olejnik and Algina 2000) that statistically significance should not be used alone for the interpretation of a study's outcome (Page 2014) and should be considered along with effect size. A number of comparative studies that adopted ANOVA and independent *t* tests (Cortizo *et al*. 2010; Francis and Shannon 2013; Gee 2014), did not consider the effect size, which questions the internal validity of these studies.

2.6. Blended Learning Tools

The first step toward making blended learning a success in your learning environment is to familiarize yourself with the theories and models of blended learning. The right blend of instructional modalities, delivery media or web-based technologies (Graham 2006) should be selected based on the required mode of delivery, be it online or face-to-face. Recent experimentation and developments in the use of social software (Wikis,Weblogs) and social

media (Facebook, Flickr) and advancements in the domain of blended learning have had a positive effect on the range of tools that are available to use in a blended learning environment. These changes have enabled teachers to move from the use of static content including text, illustrations and photos to an interactive learning environment that uses animation, video and web based tools.

A common blended learning tool that is referenced by many university advocates of blended learning and forums alike is the use of digital media based learning tools, including screencasts, audio recordings, live webcast and video recordings. Another form of a digital media based learning tool that this study is based on is RLO's. This research will investigate the use of RLO's as a blended learning tool, a means of incorporating simple low-risk tools to support face-to-face learning in the first step to a broader adoption of blended learning (Francis and Shannon 2013). The researcher is aware that there is no dedicated formula for a blended approach, however realises the importance of designing a blend in which the pedagogy is rich and designed to improve student learning (Osguthorpe and Graham 2003).

2.7. What are Reusable Learning Objects?

Similar to the term Blended Learning, the research into Learning Objects (LO's) has identified huge discrepancies in the definition of LO's. This study adopts the definition from the Learning Technology Standards Committee (LTSC) in its definition that LO's are "any entity, digital, or nondigital, which can be used, reused, or referenced during technology supported learning". LO's are used commonly as a method of sharing digital educational content and have been widely researched from many different perspectives, however the issue of reuse appears to be the most common (Wiley 2002; Polsani 2003; Caswell *et al.* 2008). The main benefit of LO's that institutions focus on is their potential for reuse, which is where the term RLO's is generated from. RLO's engage the learner in an interactive learning experience, in which the learner has flexibility in how they use, access, share and re-use the resources, promoting flexible and autonomous learning (Bath-Hextall *et al.* 2011; Stuart 2013).

2.7.1. Benefits of using Reusable Learning Objects

Recent studies of RLO's highlight the potential of these learning tools in relation to their design (Boyle 2003; Krauss and Ally 2005) cost effectiveness (Gee *et al.* 2014; Sampson and Zervas 2011), Learning Object Repositories (Baker 2006; Broison *et al*. 2005). The researcher acknowledges the importance of these factors, however, due to the word limit

restriction in this dissertation, this study will focus on their effectiveness as a learning tool. Russell *et al.* (2013) highlight in their study, one the few studies into RLO's within the Irish HE sector, how RLO's can enhance the student educational experience and assists in facilitating the student transition to higher education. These relationships have also been identified by Windle *et al.* (2011), whose study also shows that RLO's are an effective educational intervention in an area of study that students traditionally find difficult, such as design. While there is a range of studies that have evaluated the use of RLO's across various modules, the researcher has not sourced any known studies that have adopted the use of RLO's in teaching CAD in a full time or online capacity.

2.8. Challenges Associated with Reusable Learning Objects

With the evident positive effects of RLO's, it would be easy to become overoptimistic about their potential and oblivious to the challenges that need to be considered. Research into the domain of RLO's emphasizes some of the challenges that may affect the introduction of RLO's in a blended learning approach. These factors need to be considered during the initial development stage. Some of the most common factors that are evident in the literature (Hodgins 2005; Parrish 2004; Raspopovic *et al*. 2016; Yassine *et al*. 2016) relate to (1) Design of RLO's, (2) Issues around copyright (3) Granularity and Context, (4) Utilization**.**

2.9. Evaluating the Efficacy of Reusable Learning Objects

A variety of assessment tools have been used throughout the literature including, Learning Object Review Instrument (LORI) developed by Vargo *et al*. (2003), Technology Acceptance Model (TAM) developed by Davis *et al.* (1989) in the evaluation of LO's. However, the evaluation of LO's has mainly focused around their design and development (Bradley and Boyle 2004; Vargo *et al*. 2003). There is a lack of evidence of research into the impact and effectiveness of LO's over the last decade (Kay and Knack 2009), in particular the academic performance and the users perceptions of using LO's, which justifies the need to conduct more research on the students perceptions of LO's. Assessing effectiveness through user perceptions (Lau and Woods 2008) and understanding factors that encourage the effective use of methods is critical if they are to be considered as suitable educational interventions.

Within this limited body of research into the impact and effectiveness of LO's, the common methods used to evaluate LO's include surveys (Gee *et al*. 2014; Kay and Knack 2008;

Williams *et al*. 2015; Windle *et al*. 2011), interviews (Lin and Gregor 2006; Sjoer and Dopper 2006) and importantly, the monitoring of the students use of the LO's (Draus *et al*. 2014). Kay and Knack (2009) also note an encouraging trend that is emerging in this area of research is the measure of how well the students perform in this mode of learning. To add to the current research of learning object features that may influence student learning, we should also be evaluating students' academic performance.

This study will focus on evaluating the effectiveness from the user's perspective. The main learning object characteristics that have been identified within the literature surrounding the evaluation from the user's perspective are learning, quality, and engagement. Kay and Knack (2009) investigated an evaluation scale which was based around these three constructs to evaluate the impact and effectiveness of LO's. While this scale adopts a student-centred approach for evaluation, they fail to take into consideration the students ability and their use of surveys did not convey enough qualitative analysis to provide a clear understanding of the qualities of these learning objects. This study takes into consideration all of these critical evaluation tools.

2.9.1. Learning with Reusable Learning Objects

The main attraction to this form of a blended learning tool in this study was the autonomy and flexibility that RLO's offer the students. Other important aspects to consider are pitching the RLO's at the right level (Windle *et al*. 2011), ensuring they are designed for the specific applications at hand (Parrish 2004), which is achieving the intended learning outcomes and ensuring that they are integrated into the module to support learning (Littlejohn *et al*. 2008). The successful implementation of RLO's is not just concerned with the content or the learning material that forms the RLO. Facilitators of these RLO's need to also consider how the learners will interact with them and how they fit into the larger learning experience. These three characteristics have to be present if learning is to occur. If the RLO's are of poor quality then students will not engage with them and hence no knowledge will be constructed.

2.9.2. Quality of the Reusable Learning Objects

Evaluating the quality of RLO's is essential to determine the characteristics that may enhance or diminish student learning. For the purpose of this study, the researcher will evaluate the quality of the RLO's, focusing on reusability, presentation design, content and the accessibility of the learning object, using attributes of the LORI model (Vargo *et al*.

2003) adapted to assess the students perceptions of the quality of the LO's. Kay and Knack (2009) adopt a similar approach, also examining the usability of the LO's, an approach that assesses the technical quality, with no emphasis on the pedagogical or functional qualities. This approach is also recommended by Paulsson and Naeve (2006). In their study they argue that pedagogical qualities be evaluated separately as pedagogical content is generally of good quality.

2.9.3. Engagement with Reusable Learning Objects

When evaluating the effectiveness of a learning object it is critical to consider the degree to which a learning object engages and motivates the learners (Kay and Knack 2009). This study will adopt a similar approach used by Oliver and McLoughlin (1999) and Lin and Gregor (2006) in evaluating engagement. Lau and Woods (2008) and Leacock and Nesbit (2007) are of the opinion that the learners attitudes and motivation have a strong influence on the students engagement with the LO's. Ayres (2005) further notes that reduced intrinsic motivation, resulting in reduced cognitive effort may arise if the presented material is not highly relevant. LO's that match the ability of the learner, can increase motivation levels and self-efficacy (Leacock and Nesbit 2007), which Oliver and McLoughlin (1999) argues, are critical to promoting engagement in learning objects.

2.10. Reusable Learning Objects as a Blended Learning Tool

RLO's that are well designed will easily migrate across different learning platforms, face-to-face, online and blended learning. The nature of blended learning provides an ideal environment "that structures access to these learning objects" (Beetham and Sharpe 2013, p. 208). This study focuses on blending RLO's into an undergraduate module, available through a dedicated VLE, to complement the classroom teaching. The benefits and characteristics of RLO's that have been discussed are aligned with the benefits that blended learning has to offer HEI's. The use of RLO's in a blended learning approach, offer a system to adapt to the new generation of students, in relation to culture, learning styles and their technological ability.

2.11. Conclusion

This section has explored the available literature on the opportunities proposed by adopting blended learning as a model of delivery in higher education. This was discussed from

different perspectives, including its benefits as a cognitive tool and the potential of assisting higher education institutes in transforming their mode of learning, to be in a position to cater for the diverse cohort of students coming through the system. The challenges of a blended learning approach were also discussed, identifying aspects that may affect the effectiveness of this environment. The effectiveness of using RLO's as a blended learning tool was examined in detail, which highlighted gaps in the literature in relation to evaluating the student's perceptions of using RLO's in a blended environment, justifying the need to further explore the use of RLO's as a blended learning tool. In light of this information and supported by significant studies in the area of blended learning (Garrison and Kanuka 2004; Means *et al*. 2009), the researcher feels that this study will assist in the research to explore "the impact of blended learning in achieving more meaningful learning experiences" (Garrison and Kanuka 2004, p.104). The following chapter will describe the implementation of the study, the research design strategy, the data collection techniques and analytical procedures and the evaluation of all the collected data.

Section Three: Implementation and Evaluation

3.1. Introduction

This section commences by highlighting the main research question and giving an insight into sub-research questions and the research objectives of the study. It then continues with an overview of the research methodology used in the study, a description of the site selection and research participants, the researcher's philosophy and a detailed overview of the research techniques and procedures, including the data collection materials and analysis. Upon completion of the research methodology the section then moves into the evaluation of the research data, presenting the hypothesis, findings and results of the study drawing from the associated literature.

3.2. Research Question and Objectives

This study aimed to answer the main research question, "How does blended learning compare with traditional classroom delivery in an undergraduate engineering module, in terms of academic achievement and student perceptions?". This research question formulated sub-questions that the study aimed to answer.

Sub-Research Questions:

1. Is there a significant difference in the students overall academic grades between the experimental group and the control group?
2. Is there a significant difference in the students' continuous assessment grades between the experimental group and the control group?
3. Is there a significant difference in the students' end of term exam grades between the experimental group and the control group?
4. Does the participation rates of the RLO's have an effect on the students' academic grades?
5. Does the students' previous experience of CAD influence their participation rates of the RLO's?
6. What were the attitudes of the students in relation to their blended learning experience?

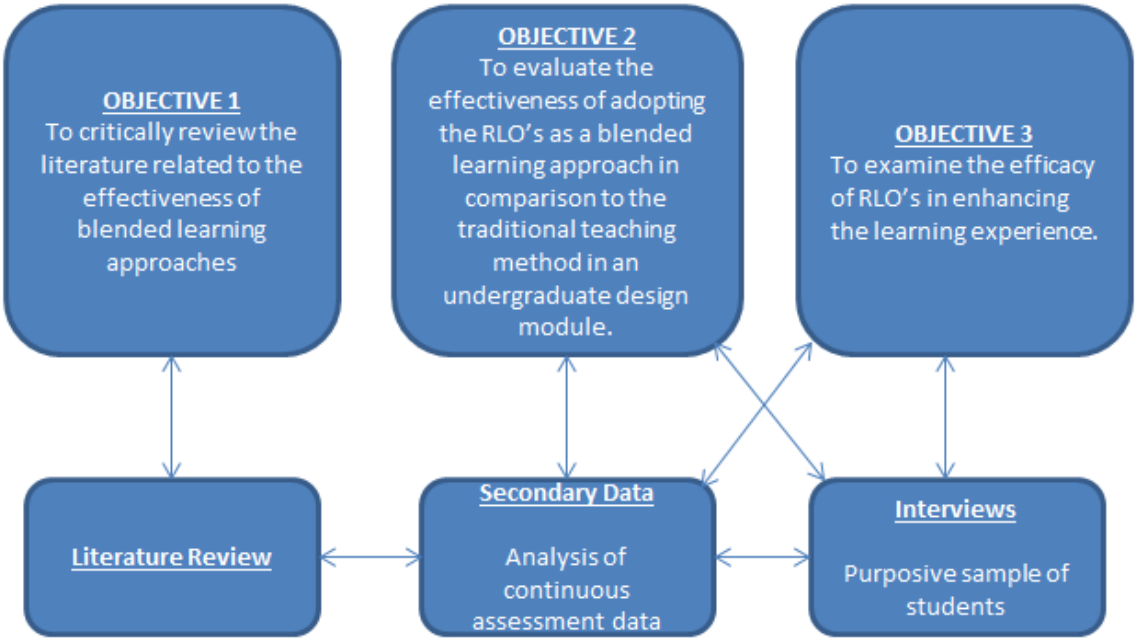
The study research objectives are outlined as follows:

1. To critically review the literature related to the effectiveness of blended learning approaches.

2. To evaluate the effectiveness of adopting the RLO's as a blended learning approach in comparison to the traditional teaching method in an undergraduate design module.

3. To examine the efficacy of RLO's in enhancing the learning experience.

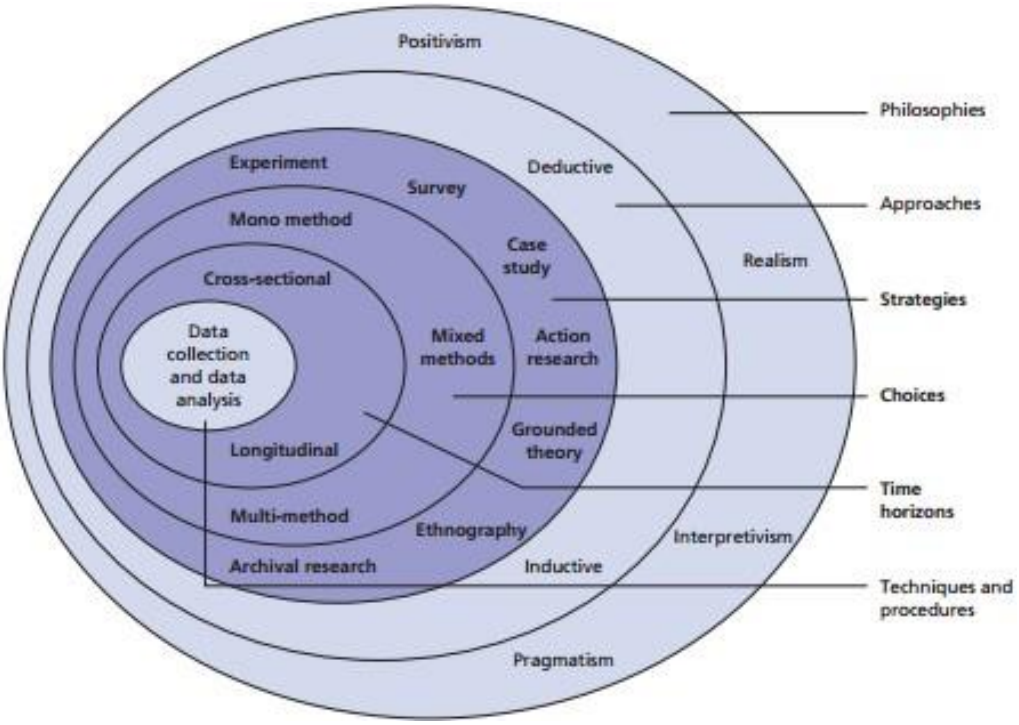
Figure 3-1 Research Objectives and Chosen Methodology



3.3. Research Methodology

Research methodology is a systematic process of enquiry and analysis to find ways to a problem (Burns 2000). The primary aim of the research was to investigate the effectiveness of RLO's as a blended learning tool in an undergraduate engineering design module. The approach proposed by Saunders, with the use of the research onion (Saunders *et al*. 2009), as shown in Figure 3.2, helped the researcher to decide on a suitable methodology into how this study would be conducted and controlled. This research process gave direction to the study, allowing the researcher to peel away the layers of the research, to illustrate what choices, paradigms and strategies had to be considered before undertaking any research.

Figure 3-2 Research Onion



Source: Saunders *et al*. (2009, p.108)

3.3.1. Research Philosophy and Approach

In research philosophy, positivism, a philosophy that purely quantitative approaches are based on, interpretivism or constructivism, a philosophy that purely qualitative approaches are based on are the two main traditional methods used. However, these methods have changed and according to Johnson *et al*. (2007, p.117) "we currently are in a three methodological or research paradigm world, with quantitative, qualitative, and mixed methods research all thriving and coexisting". The mixed methods approach, viewed as the third research paradigm (Johnson *et al*. 2007), has developed rapidly as a viable alternative to quantitative and qualitative paradigms.

A pragmatic research philosophy allows mixed methods to be used as the method of collecting data, allowing the researcher to be objective and subjective in their analysis (Saunders *et al*. 2009). Creswell (2009) also argues that a pragmatic research approach has a strong philosophical relationship with this form of data collection, which is rationalised by the research question (Creswell and Plano Clark, 2011). Based on the research topic, research question and research objectives, the researcher proposed to adopt a deductive approach

underpinned by a pragmatic research philosophy, to conduct a quasi-experimental study (Campbell *et al.* 2008) using a mixed methods approach as the data collection method to determine if a blended learning approach can enhance student learning.

3.3.2. Research Strategy

Based on the study research question, sub-research questions and research objectives, it was decided that a mixed methods approach would be used, combining aspects of quantitative and qualitative data to evaluate this intervention. A mixed methods research process model developed by Johnson and Onwuegbuzie (2004) further reinforced the researchers' decision and provided a clear structure to follow. This method allowed the researcher to "integrate the information and compare one data source with the other" (Creswell 2009, p. 214) and provide both breadth and a depth of understanding (Creswell and Plano Clark 2011; Johnson *et al.* 2007). This study used a descriptive, quantitative approach that also utilised semi-structured interviews to examine the students' perceptions of their experience of being involved in this blended learning environment. This approach provided richer detail, reinforcing the findings of the study and also assisted in ensuring that reliability and validity was adhered to throughout the study.

3.3.3. Site Selection

The Institute of Technology Sligo is set on a 72 acre site and is situated in the town of Sligo. It opened in 1970 as a Regional Technical College and adopted its present name in 1997 and currently has three schools and nine departments. It currently has 6000 students in an online and full-time capacity. This study was conducted in the Mechanical and Electronic engineering department which consists of 1600 students, 49 per cent of the current full time student population. Due to the online resources that IT Sligo has to offer, academic staff are often encouraged to pursue the area of blended learning in their courses.

3.3.4. Participant Selection

This quasi-experimental study involved 38 students from the 2014/2015 academic year, as the control group and 41 students from the 2015/2016 academic year, as the experimental group. The sample population was selected using non-probability sampling in the form of purposive sampling. According to Saunders *et al.* (2011, p.237), purposive sampling enables you to use your judgement to choose the population that enable you to answer your research question and meet your objectives. Two purposive samples of all the available first year

mechanical engineering students previously mentioned from the 2015/2016 academic year and the 2014/2015 academic year were used in the statistical analysis of the study. As the sample size is atypical and selected, this means that this method contributed more to internal validity than external validity. All the students enrolled in this module had access to RLO's made available through the dedicated moodle page, however, only the cohort of students that entered through the CAO system over the last two academic years were considered for the statistical analysis, if they agreed to partake in the study. It should be noted that the students are familiar with the use of VLE's as 75 per cent of their modules in their first year of study adopt the use of a moodle page as a means of learning support.

Both groups experienced the same learning conditions, including the same lecturers, face-to-face instructional content, hand-outs, continuous assessment exercises throughout the duration of the modules Design 101/102 and end of term exams. Initial contact with the students regarding the nature of the study occurred after approval was granted from the ethics committee and all the available students agreed to participate in this study and signed the consent form as shown in Appendix D.

3.3.5. Time Horizon

The students had access to the RLO's through the dedicated moodle page in the modules, Design 101 in semester one and Design 102 in semester two. These modules ran for thirteen weeks each semester during the 2015/2016 academic year. Upon receiving approval from the ethics committee, the students were informed of the researchers aim to evaluate the effectiveness of this blended learning approach, explaining in detail the meaning of blended learning to the students. The students' grades from both modules were gathered and analysed upon completion of the academic year. The time line of the study events is shown in Table 3.1

Table 3.1 Research Time Horizon

September 2015- May 2016	RLO's available through dedicated moodle page.
November 2015-August 2016	Literature Review, Research Methodology.
December 2015	Research Proposal
March 2016	Ethics consent- Approval
March 2016-June 2016	Monitoring participation levels on the moodle page.
June 2016	Quantitative and Qualitative data collection
June 2106-August 2016	Statistical analysis of data, Findings, Discussions and Conclusions

3.3.6. Technique and Procedure

This section highlights the data collection and analysis techniques and procedures that were adopted in this study.

3.3.6.1. Quantitative Data Collection Method

Students assessment grades were collected upon completion of the modules and analysed to determine whether academic performance improved with the use of the blended learning approach, an approach adopted by similar studies (Mersal and Mersal 2014; Vernadakis *et al.* 2011; LaMeres and Plumb 2014). The researcher examined the students overall grades and further analysis was performed through the breakdown of the grades in terms of continuous assessment, exams and individual exercises that were identified and linked to the students participation rates in accessing the RLO's. The students' participation rates in accessing the RLO's was monitored via the moodle statistic tool. This allowed the researcher to determine their overall usage level and the access levels for individual exercises for correlation purposes. In this module a survey is conducted to determine the students' prior knowledge of design in relation to the subjects undertaken in post-primary education. This information was available and used to address any issues of bias that may affect the nature of the study.

3.3.6.2. Quantitative Data Analysis Technique

A statistical analysis, in the form of the independent *t* test was used to determine if significant differences existed between the mean scores of the students that adopted a blended learning

approach throughout the academic year, with historical grades of students from the previous academic year that were taught using traditional face-to-face learning approaches only, a similar approach used by (Gonzalez *et al.* 2010; Vernadakis *et al*. 2011). Statistical significance alone is seen "as an unacceptable index of effect" (Cohen *et al*. 2011, p.616) and should be accompanied with information about the effect size. Good research should always provide an estimate of the effect size when reporting a *p* value (Thompson 2002) and its combined use enables researchers to examine the relationships within the data (Nakagawa and Cuthill 2007). This is a common approach adopted by similar studies in this field (Gonzalez *et al*. 2010; Rovai and Jordan 2004; Sitzmann *et al*. 2006). This approach also encourages researchers to report and interpret effect sizes in the context of previous research. Correlation analysis was also used to test if any relationships, positive or negative, were present in the study.

3.3.6.3. Qualitative Data Collection Method

Qualitative methodologies use a range of data sources, including open-ended questionnaires, focus groups and interviews. This study used semi-structured interviews to reflect the experience of the participants in the learning process (Smyth *et al*. 2012), to compare data collected across the interviewees (Cohen *et al*. 2007) and to add more depth to the quantitative findings (Cohen *et* al. 2011; Thomas 2011), a common approach used in research (Domegan and Fleming 1999).

Pilot Study

The interview questions were piloted on another cohort of students that also had access to the RLO's. These students were part of a special purpose award programme that ran for one semester. As part of this programme they studied the module Design 101. It was decided that this cohort of students would also be allowed access to this blended approach due to their lack of experience of CAD. The interview questions were used on four of these students who volunteered to assist in the pilot study, to ensure the questions were relevant and coherent to what the study was evaluating. The pilot study was also beneficial in allowing the researcher to become comfortable and familiar with the interview process. Based on the outcome of the pilot study, the researcher decided that no modifications were needed.

The face-to-face interviews took place in a room that the students were familiar with in IT Sligo as it was felt that this may make the interview experience more natural. The individual interviews were arranged at the convenience of the interviewees, where they were reminded of their right to withdraw from the study at any time, as highlighted in the study information sheet (Appendix B) that accompanied the study consent form (Appendix D). A total of six interviews were conducted. Ten participants were selected based on their academic performance and their usage of the RLO's and six respondents agreed to be interviewed. The student interview questions were adapted from qualitative research questions sourced in the literature surrounding blended learning (Garrison and Vaughan 2008; Krauss and Ally 2005; Poon 2012; Williams *et al*. 2015; Windle *et al.* 2011). The length of the interviews ranged from 25-37 minutes with an average time of 32 minutes. The interviews were recorded on a smart phone and transferred to a password protected computer to protect the data.

3.3.6.4. Qualitative Data Analysis Technique

A common qualitative data analysis tool is the use of thematic data analysis using codes to highlight segments of text with similar content into categories that can be brought together for a final analysis (Smyth *et al*. 2012). However, for the purpose of this study and due to time constraints and a lack of experience, the use of thematic analysis in the form of codes was not adopted. This view is supported by Bogdan and Biklen (1997) who identify the need for considerable experience and a strong theoretical background in qualitative research to consider the use of thematic data analysis. The researcher considered the basic format of this form of content analysis and applied it to the interview questions. The sections that were administered in the interview questions (Experience, Usage and Recommendations) assisted the researcher in the content analysis of the data to identify similar themes in regard to the students' perceptions of the blended learning experience. The recorded interviews were transcribed and thoroughly checked for accuracy of transcription. After reading through each script carefully, to notice "interesting things" (Seidel 1998, p.6), any minor and major themes were categorised for the final analysis which assisted in the triangulation of the data.

3.3.7. Reliability and Validity

A good methodology will serve to enhance the validity and reliability of the research and the use of triangulation in this study will also assist the process (Cohen *et al*. 2005). This research study was designed, based around previous research in this area, to ensure its reliability and

to minimise any issues of bias and any other threats of validity. This is an important aim to achieve in both qualitative and quantitative research; and is the primary responsibility of every good researcher. The interview questions were adapted from questions sourced in the literature surrounding blended learning (Garrison and Vaughan 2008; Krauss and Ally 2005; Poon 2012; Williams *et al*. 2015; Windle *et al* 2011).

3.3.7.1. Validity

To ensure that this comparative study was valid, the CAO points from students of the 2015/2016 and 2014/2015 academic year were statistically analysed using the student *t* test to determine if the students from the 2015/2016 academic year and the students from the 2014/2015 academic year were initially equivalent. Similar studies use the university entrance exam grades (Castano *et al*. 2014; Cortizo *et al*. 2010). With a p-value obtained of p= 0.859 > 0.05, see Table 3.2, which is significantly greater than 0.05, the analysis shows that there is no difference statistically between the two year groups.

Table 3.2 Comparison of CAO entry points

t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015	*2015/2016*
Mean	304.8684211	301.8292683
Variance	5352.009246	6223.445122
Observations	38	41
Hypothesized Mean Difference	0	
df	77	
t Stat	0.17766029	
P(T<=t) one-tail	0.429728157	
t Critical one-tail	1.664884537	
P(T<=t) two-tail	0.859456313	
t Critical two-tail	1.991254395	
Decision	Do not reject null hypothesis	

A pilot study was also used for the interview questions to determine if the questions were reliable and valid. The interviewees were able to review the written transcripts to ensure that they were an accurate representation of the interview. All the interviewees validated the content of the transcripts.

3.3.7.2. Dealing with Bias

The researcher ensured that all the data was prepared and analysed in a rigorous manner to maintain a minimal level of bias. As part of the quantitative analysis, the researcher removed himself from the assessment of this module to eliminate any evaluation bias, in relation to the grading of the students work (Gonzalez *et al.* 2010).

3.3.8. Research Ethics

This study adhered to Letterkenny Institute of Technology research ethics policy in accordance with the Declaration of Helsinki. Due to the type of study proposed, a number of factors were considered including:

1. the confidentiality of information provided by those taking part in the research;
2. the anonymity of the respondents;
3. consents which were required;
4. the transparency to both researchers and those taking part in the research as to the purpose, methods, application of the research and any risks involved;
5. the legal restrictions governing access to or the use of research resources and data.

Students from both academic years were asked to give consent to participate in the study. Students who were under 18 years of age did not participate in the study, however they were still allowed access to the RLO's. Only the data from those students who voluntarily agreed to participate in the study were included.
Consent from IT Sligo was also approved, from the Head of Research and the Student Affairs manager. The researcher had already received consent from the Student Affairs manager to obtain the CAO points required to ensure the research methodology was valid for this study.

3.4. Evaluation

This section focuses on the analysis of the data that underpins the objectives of this study. The data for this study was gathered using both quantitative and qualitative techniques and analysed with the intention of "mutually illuminating" (Bryman 2007, p.8) the findings. The data is analysed based around the research question and sub-research questions and for clarity purposes, the information gained from each source is presented alone. It is however, cross-referenced between different data sources where possible to gain a greater depth of analysis. The findings of the study are presented, drawing from issues identified in the research and the

literature review. Based on these findings, the results are presented, highlighting the outcomes and themes in this study.

3.4.1. Research Findings & Results

The purpose of this research study, that adopted a mixed methods approach, was to investigate the effectiveness of RLO's as a blended learning tool in an undergraduate engineering design module. To accomplish this, statistical techniques in the form of independent *t* tests and correlation analysis were adopted to test the hypothesis in the study and also semi-structured interviews to acquire information on the students' experience of this blended approach, were used to obtain data relevant to achieving the purpose of this study.

The quantitative data revealed that there was no statistical difference in the mean of the overall grades between the control group and the experimental group that adopted a blended learning approach by accessing a series of RLO's. Nine independent *t* tests were conducted to test the hypothesis in the study. The null hypothesis was rejected for seven of these tests, highlighting no statistical difference between overall grades, continuous assessment grades and an individual exercise identified in the study. However, the null hypothesis was not rejected for two of the tests, indicating that there was sufficient statistical evidence to suggest that the blended learning approach had a significant impact on the students' end of term exam grades in the module Design 102. Furthermore, the magnitude of the difference between the groups, using Cohen's *d*, was considered (Fan 2001; Glass 1976) to determine the effect size. Based on these findings, other variables were considered including attendance and previous experience of using CAD and the students' access rates of the RLO's. Further tests revealed there was also sufficient statistical evidence to suggest that the students' previous experience of CAD had a significant difference in their usage of the RLO's. Correlation analysis was also performed to determine if relationships were evident between the variables. While the correlations between the students' RLO usage and their overall grades in both modules are not statistically significant, a statistical significant positive relationship was found between the students' RLO usage and their end of term exam grades in Design 102.

The qualitative data contained findings similar to other studies in this domain. The student responses reinforced the findings from the quantitative data and also provided further information that would not have been elicited through the quantitative data. Overall, the students were very satisfied with this blended learning approach, which could be seen as an

indicator of the quality of learning, a view also supported by (Lopez *et al*. 2011). The RLO's were viewed as a means of reinforcing their understanding of material covered in class, in a flexible manner, available through an online medium.

3.4.2. Data Analysis

This section presents the results determined relative to each sub-research question and discusses the findings of the outcomes.

3.4.2.1. Sub-Research Question 1.

RQ.1. Is there a significant difference in the students overall academic grades between the experimental group and the control group?

Overall Module Results and Findings

Using the main assessment spreadsheet for these modules, the researcher gathered the required data, in the form of the students' final grade for the modules Design 101/102 for both the 2014/2015 and 2015/2016 academic year. The results from the two independent samples were analysed using the *t* test statistical tool in Excel to determine whether significant differences existed between the mean of the final grades of the control group and the experimental group. The independent *t* test was selected as two separate groups are being compared to determine if there is a significant difference between the groups. The t-Test: Two-Sample Assuming Unequal Variances was used for all the independent t tests in the study as the sample size for both groups, n >30 (Remenyi *et al*. 2011), except for hypotheses **H7** where the sample size n <30.
For the purpose of the study the results for both modules have been analysed separately as follows:

Design 101 Module

Hypotheses:

H1$_0$. There was no significant difference in the overall grades between the experimental group and the control group in Design 101: $\mu_0 = \mu_a$

H1$_a$. There was a significant difference in the overall grades between the experimental group and the control group in Design 101: $\mu_0 \neq \mu_a$

The *t* test two-sample assuming unequal variances, see Table 3.3, shows there was no significant difference in the grades, p= 0.273 > 0.05, therefore at a 0.05 level of significance, the Null Hypothesis **H1$_0$** cannot be rejected. Therefore, there is insufficient evidence to suggest that the blended learning approach had any significant impact on the students' overall academic grades in the module Design 101. A small magnitude of difference in the means of *d* = .246 also indicates a weak association between the blended learning approach and the students' overall academic grades in the module Design 101.

Table 3.3 Comparison in the overall grades in Design 101

Module- Design 101		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 Overall Grade Design 101	*2015/2016 Overall Grade Design 101*
Mean	62.93421053	67.20363918
Variance	257.8671764	335.2883649
Observations	38	41
Hypothesized Mean Difference	0	
df	77	
t Stat	-1.103696424	
P(T<=t) one-tail	0.136581077	
t Critical one-tail	1.664884537	
P(T<=t) two-tail	0.273162155	
t Critical two-tail	1.991254395	
Decision	Do not reject null hypothesis	

Design 102 Module

Hypotheses:

H2$_0$. There was no significant difference in the overall grades between the experimental group and the control group in Design 102: $\mu_0 = \mu_a$

H2$_a$. There was a significant difference in the overall grades between the experimental group and the control group in Design 102: $\mu_0 \neq \mu_a$

The *t* test two-sample assuming unequal variances, see Table 3.4, shows that there was no significant difference in the grades, p= 0.084 > 0.05, therefore at a 0.05 level of significance,

the Null Hypothesis **H1$_0$** cannot be rejected. Therefore, there is insufficient evidence to suggest that the blended learning approach had any significant impact on the students' overall academic grades in the module Design 102. However, a magnitude of difference in the means of d = .386 indicates a small to moderate association between the blended learning approach and the students' overall academic grades in the module Design 102.

Table 3.4 Comparison in the overall grades in Design 102

Module- Design 102		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 Overall Grade Design 102	*2015/2016 Overall Grade Design 102*
Mean	61.61842105	67.41943829
Variance	203.4793975	238.543227
Observations	38	41
Hypothesized Mean Difference	0	
df	77	
t Stat	-1.746253159	
P(T<=t) one-tail	0.042351993	
t Critical one-tail	1.664624645	
P(T<=t) two-tail	0.084703987	
t Critical two-tail	1.990847069	
Decision	Do not reject null hypothesis	

These results indicate that there is an overall improvement in the students' academic grades, however the evidence suggests that there is no statistical significant between the experimental group and the control group, consistent with other findings (Demirer and Sahin 2013; Vernadikis *et al*. 2011). These studies also based their research on first year students, over a duration of 14-15 weeks, both using pre-tests and post-tests. This study adopts a broader approach, evaluating the breakdown of results in much greater detail (Olitsky and Cosgrove 2014) at the end of the modules, an approach that LaMeres and Plumb (2014) argue will give a better reflection of the outcome of the intervention.

However, through detailed analysis of the collected data, the researcher observed through the breakdown of results that the students in the blended approach performed significantly better in their end of term exams. The following analysis highlights the breakdown of the overall

grades in terms of their continuous assessment and end of term exam results and seeks to add to the research in this study.

3.4.2.2. Sub-Research Question 2.

RQ.2. Is there a significant difference in the students' continuous assessment grades between the experimental group and the control group?

Hypotheses:

$H3_0$. There was no significant difference in the continuous assessment grades between the experimental group and the control group in Design 101: $\mu_0 = \mu_a$

$H3_a$. There was a significant difference in the continuous assessment grades between the experimental group and the control group in Design 101: $\mu_0 \neq \mu_a$

The *t* test two-sample assuming unequal variances, see Table 3.5, shows there was no significant difference in the continuous assessment grades, p= 0.109 > 0.05, therefore at a 0.05 level of significance, the Null Hypothesis **$H3_0$** cannot be rejected. Therefore, there is insufficient evidence to suggest that the blended learning approach had any significant impact on the students' continuous assessment grades in the module Design 101. However, a magnitude of difference in the means of d = .452 indicates a moderate association between the blended learning approach and the continuous assessment grades in the module Design 101.

Table 3.5 Comparison of continuous assessment grades in Design 101

Module- Design 101		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 CA Grade Design 101	*2015/2016 CA Grade Design 101*
Mean	64.69996129	70.68421053
Variance	349.4530336	196.059744
Observations	38	41
Hypothesized Mean Difference	0	
df	74	
t Stat	-1.617795361	
P(T<=t) one-tail	0.054980852	
t Critical one-tail	1.665706893	
P(T<=t) two-tail	0.109961704	
t Critical two-tail	1.992543495	
Decision	Do not reject null hypothesis	

Hypotheses:

H4$_0$. There was no significant difference in the continuous assessment grades between the experimental group and the control group in Design 102: $\mu_0 = \mu_a$

H4$_a$. There was a significant difference in the continuous assessment grades between the experimental group and the control group in Design 102: $\mu_0 \neq \mu_a$

The *t* test two-sample assuming unequal variances, see Table 3.6, shows there was no significant difference in the continuous assessment grades, p= 0.302 > 0.05, therefore at a 0.05 level of significance, the Null Hypothesis **H4$_0$** cannot be rejected. Therefore, there is insufficient evidence to suggest that the blended learning approach had any significant impact on the students' continuous assessment grades in the module Design 102. A small magnitude of difference in the means of *d* = .233 also indicates a weak association between the blended learning approach and the students' continuous assessment grades in the module Design 102.

Table 3.6 Comparison of continuous assessment grades in Design 102

Module- Design 102		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 CA Grade Design 102	*2015/2016 CA Grade Design 102*
Mean	57.05263158	61.32668145
Variance	282.4295875	390.588614
Observations	38	41
Hypothesized Mean Difference	0	
df	76	
t Stat	-1.037864432	
P(T<=t) one-tail	0.151312009	
t Critical one-tail	1.665151353	
P(T<=t) two-tail	0.302624017	
t Critical two-tail	1.99167261	
Decision	Do not reject null hypothesis	

The workload involved in the continuous assessment is normally a concern for the students. Students do not place enough emphasis on their continuous assessment, as it is time consuming. While the RLO's assist the students in completing the exercises, the researcher is of the opinion that the results of the continuous assessment exercises not being statistically significant is down to a lack of effort from the students, although this is a common trend in these modules which needs to be addressed.

3.4.2.3. Sub-Research Question 3.

RQ.3. Is there a significant difference in the students' end of term exam grades between the experimental group and the control group?

End of Term Exam Results

Hypotheses:

H5$_0$. There was no significant difference in the end of term exam grades between the experimental group and the control group in Design 101: $\mu_0 = \mu_a$

H5$_a$. There was a significant difference in the end of term exam grades between the experimental group and the control group in Design 101: $\mu_0 \neq \mu_a$

The *t* test two-sample assuming unequal variances, see Table 3.7, shows there was no significant difference in the end of term exam grades, p= 0.237 > 0.05, therefore at a 0.05 level of significance, the Null Hypothesis **H5$_0$** cannot be rejected. Therefore, there is insufficient evidence to suggest that the blended learning approach had any significant impact on the students' end of term exam grades in the module Design 101. A small magnitude of difference in the means of *d* = .266 also indicates a weak association between the blended learning approach and the end of term exam grades in the module Design 101.

Table 3.7 Comparison of end of term exam grades in Design 101

Module- Design 101		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 End of Term Exam Grade Design 101	*2015/2016 End of Term Exam Grade Design 101*
Mean	63.71052632	69.70731707
Variance	512.3193457	485.9621951
Observations	38	41
Hypothesized Mean Difference	0	
df	76	
t Stat	-1.191406446	
P(T<=t) one-tail	0.118600741	
t Critical one-tail	1.665151353	
P(T<=t) two-tail	0.237201481	
t Critical two-tail	1.99167261	
Decision	Do not reject null hypothesis	

H6$_0$. There was no significant difference in the end of term exam grades between the experimental group and the control group in Design 102: $\mu_0 = \mu_a$

H6$_a$. There was a significant difference in the end of term exam grades between the experimental group and the control group in Design 102: $\mu_0 \neq \mu_a$

The *t* test two-sample assuming unequal variances, see Table 3.8, shows there was a significant difference in the mean of the end of term exam grades, p= 0.046 < 0.05, therefore at a 0.05 level of significance, the Null Hypothesis **H6$_0$** can be rejected and **H6$_a$** is accepted. Therefore, there is sufficient statistical evidence to suggest that the blended learning approach had a significant impact on the students' end of term exam grades in the module Design 102.

Furthermore, the magnitude of the difference between groups, using Cohen's *d*, was considered (Fan 2001; Glass 1976) determining a small to moderate effect size of *d*= .37, further supporting the significance of this finding.

Table 3.8 Comparison of end of term exam grades in Design 102

Module- Design 102		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 End of Term Exam Grade Design 102	*2015/2016 End of Term Exam Grade Design 102*
Mean	66.18421053	73.51219512
Variance	263.4516358	251.1060976
Observations	38	41
Hypothesized Mean Difference	0	
df	76	
t Stat	-2.027939139	
P(T<=t) one-tail	0.023035741	
t Critical one-tail	1.665151353	
P(T<=t) two-tail	0.046071482	
t Critical two-tail	1.99167261	
Decision	Reject null hypothesis	

Although there was insufficient evidence to suggest that the blended learning approach had any statistical significant impact on the students' overall academic grades in both modules, there was evidence to suggest that the students' grades had increased in both modules.
As shown, see Table 3.8, there is sufficient statistical evidence to suggest that the blended learning approach had a significant impact on the students' end of term exam grades in the module Design 102. This is a significant finding, similar to (Alonso *et al*. 2011; Cortizo *et al*. 2010) and one that differs from many other related studies (Demirer and Sahin 2013; Mahnken *et al*. 2011; Vernadikis *et al*. 2011). Based on this finding, the researcher had the exam content and marking scheme evaluated to ensure there was consistency between the exams from both academic years. As anticipated, the exams were identical in terms of what learning outcomes needed to be assessed. The exams had the same structure including an equal number of features, assemblies and drawings. The same marking scheme was used for both academic years.

At this point of the study, other variables that may have contributed to this outcome including attendance rates and students previous experience were considered. These factors formulated further sub-research questions that the study aimed to test. Studies show that low class attendance rates may affect the outcomes of these approaches, (Davis 2011; Gottfried 2010; Paisey and Paisey 2004). Interestingly, as well as highlighting that there was no difference statistically between the two year groups (Entry CAO points), their average attendance across both modules were very similar at 73 per cent, see Table 3.9.

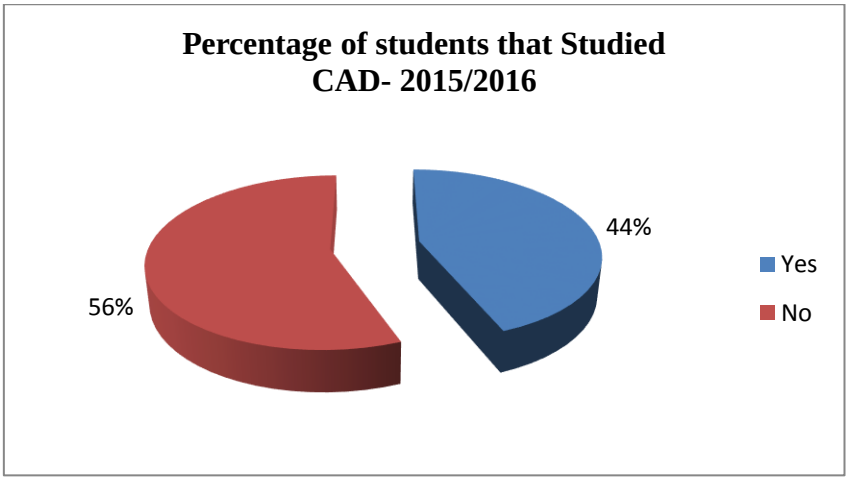
Table 3.9 Average attendance for both year groups

2014/2015 Average Attendance			2015/2016 Average Attendance		
AB	76.20		AB	65.88	
CD	70.13		CD	80.00	
Overall	73.16		Overall	72.94	

Students Previous Experience

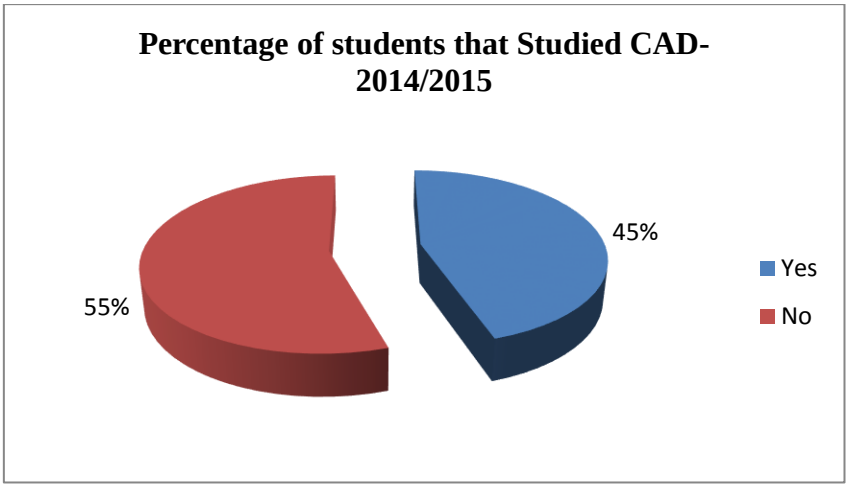
Castano *et al*. (2014) evaluate students' previous experience also; however they examine the relationship with technology, which is a very broad insight into their level of ability. This study uses a more defined approach. A survey of the students' prior learning is undertaken at the beginning of Design 101 to gain an insight into the learners' previous experience of the design process. As part of this survey it was determined that 44 per cent of the students from the 2015/2016 academic year have previous experience with CAD, see Figure 3.3.

Figure 3-3 Percentage of students that had previous experience of using CAD from the 2015/2016 academic year



This is a similar percentage to the students from the 2014/2015 academic year, see Figure 3.4.

Figure 3-4 Percentage of students that had previous experience of using CAD from the 2014/2015 academic year



As identified previously, the aim of the implementation of this blended approach was to assist the students with no previous experience in the design process and using a form of CAD software. To triangulate aspects of the data from the semi-structured interviews, the following research question was formulated to determine if the students' previous experience of CAD influenced their participation rates of the RLO's?

3.4.2.4. Sub-Research Question 4.

The students' previous experience of CAD was answered in the survey as a Yes/No reply. For the purpose of the nominal analysis a dummy variable was used (Lopez *et al*. 2011; Olitsky and Cosgrove 2014), that being Yes=1 and No=0.

RQ.4. Does the students' previous experience of CAD influence their participation rates of the RLO's?

H7$_0$. The students' previous experience of CAD had no significant difference in their participation rates of the RLO's: $\mu_0 = \mu_a$

H7a. The students' previous experience of CAD had a significant difference in their participation rates of the RLO's: $\mu_0 \neq \mu_a$

In this test, n < 30, therefore a test was required to determine the equality of variance. The F test Two Sample for Variance analysis tool in Excel was used to test the difference between the two variances. As the significant value p= 0.195 > 0.05, the variances are assumed to be equal. Hence, the *t* test two-sample assuming equal variances, see Table 3.10, shows there was a significant difference, p= 0.019 < 0.05, therefore at a 0.05 level of significance, the Null Hypothesis **H70** can be rejected and **H7a** is accepted. Therefore, there is sufficient statistical evidence to suggest that the students' previous experience of CAD had a significant difference in their participation rates of the RLO's. Furthermore, the magnitude of the difference in the means was high at *d* = .76, further supporting the significance of this finding, with a strong association between how students' previous experience of CAD may influence their participation rates of the RLO's.

Table 3.10 Comparison of access rates between students with/without previous experience of CAD

t-Test: Two-Sample Assuming Equal Variances		
	Participation Rates in RLO's With No Previous Experience	*Participation Rates in RLO's With Previous Experience*
Mean	1.782608696	0.944444444
Variance	0.996047431	1.467320261
Observations	23	18
Pooled Variance	1.201474049	
Hypothesized Mean Difference	0	
df	39	
t Stat	2.429853995	
P(T<=t) one-tail	0.009904722	
t Critical one-tail	1.684875122	
P(T<=t) two-tail	0.019809444	
t Critical two-tail	2.02269092	
Decision	Reject null hypothesis	

This finding supported what the researcher had anticipated. The students that had previous experience of using this software did not avail of the use of the RLO's as much as the students with no previous experience. Therefore, it could be suggested that using RLO's as a blended learning tool allowed the students with no previous experience to improve their skills and knowledge of this software, in a shorter timeframe then in previous academic years and also improved their academic grades.
To assist in testing this theory the following sub-research question was formulated to determine if there was a relationship between the students' RLO usage and their overall academic grades.

3.2.4.5. Sub-Research Question 5.

RQ.5. Does the participation rates of the RLO's have an effect on the students' academic grades?

To measure the relationship between these two quantitative variables a correlation analysis was selected. The dependent variable (academic grades) and the independent variable (RLO usage) were used to calculate the correlation coefficient to determine the strength of the relationship between the students' RLO usage and their academic grades. Similar to the independent *t* test analysis, the researcher analysed both modules Design 101 and Design 102.
In light of hypotheses **H7**, the researcher focused this relationship around the students that had no previous experience with CAD (N=23), to determine this relationship.

Design 101 Module

Hypotheses:

$H8_0$. There is no relationship between the students' RLO usage and their overall academic grades in Design 101: $p = 0$

$H8_a$. There is a relationship between the students' RLO usage and their overall academic grades in Design 101: $p \neq 0$

The Pearson function was used in Excel to determine the coefficient, which calculated a value of r = 0.216, a low positive relationship. However, to test the hypotheses, the statistical significance had to be determined. The researcher adopted the use of the Regression analysis tool in Excel, which determined the required statistical data, see Table 3.11. A positive relationship was found, (r = 0.216, N= 23, p > .05), however this was not statistically significant.

Table 3.11 Relationship of RLO usage and overall academic grades in Design 101

Regression Statistics						
Multiple R	0.216057622					
R Square	0.046680896					
Adjusted R Square	0.001284748					
Standard Error	16.99035669					
Observations	23					
ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	296.8418811	296.84188	1.02830082	0.322099872	
Residual	21	6062.116629	288.67222			
Total	22	6358.95851				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	55.76984127	6.006998215	9.2841448	6.9979E-09	43.27760462	68.2620779
Participation Rates-RLO's in SEM 1	7.542857143	7.438335986	1.0140517	0.32209987	-7.926009356	23.0117236

Design 102 Module

Hypotheses:

H9$_0$. There is no relationship between the students' RLO usage and their overall academic grades in Design 102: $p = 0$

H9$_a$. There is a relationship between the students' RLO usage and their overall academic grades in Design 102: $p \neq 0$

A positive relationship was found, (r = 0.290, N= 23, p > .05), however this was not statistically significant, see Table 3.12.

Table 3.12 Relationship of RLO usage and overall academic grades in Design 101

Regression Statistics	
Multiple R	0.290892937
R Square	0.084618701
Adjusted R Square	0.041029115
Standard Error	11.81044342
Observations	23

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	270.7796468	270.7796468	1.941259575	0.178105386
Residual	21	2929.218048	139.4865737		
Total	22	3199.997694			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	57.94619871	4.778733877	12.1258476	6.00572E-11	48.00827758	67.88411984
Participation Rates-RLO's in SEM 2	5.249497184	3.767696413	1.393290915	0.178105386	-2.585856439	13.08485081

While hypothesis **H8** and **H9** suggest that there is no statistically significant relationship between the students' RLO usage and their academic grades the researcher believed that based on the findings of hypothesis **H6**, the relationship between the students' RLO usage and their end of term exam grades in Design 102 warranted further analysis to add to this apparent trend in their grades in this module.

End of Term Exam in Design 102

Hypotheses:

$H10_0$. There is no relationship between the students' RLO usage and their end of term exam grades in Design 102: $p = 0$

$H10_a$. There is a relationship between the students' RLO usage and their end of term exam grades in Design 102: $p \neq 0$

As shown, see Table 3.13, there is sufficient statistical evidence to suggest that there is a statistically significant positive relationship between the students' RLO usage and their end of term exam grades in Design 102, ($r = 0.439$, $N = 23$, $p > .05$), see Table 3.13.

Table 3.13 Relationship of RLO usage and end of year exam grades in Design 102

Regression Statistics	
Multiple R	0.439493252
R Square	0.193154319
Adjusted R Square	0.154733096
Standard Error	14.04437736
Observations	23

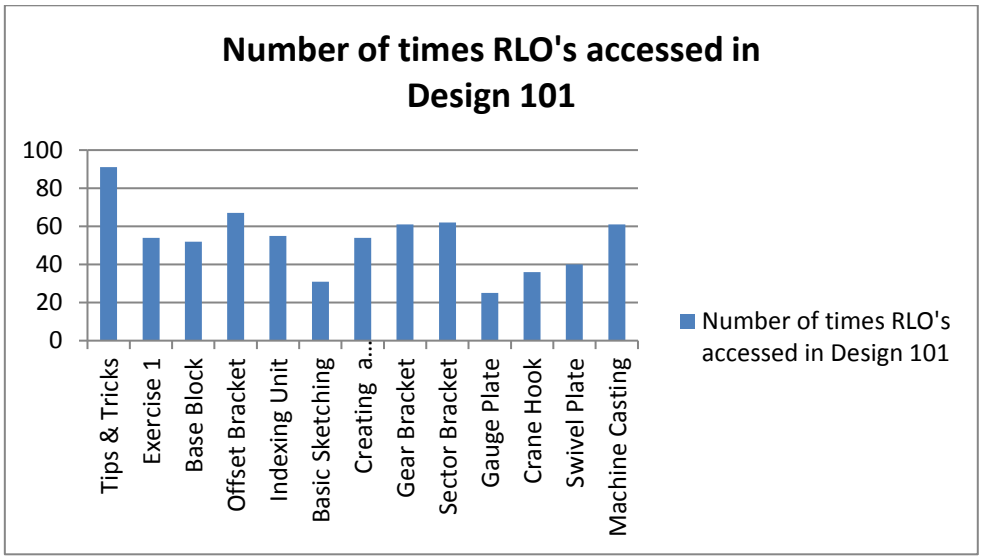
ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	991.6038845	991.6038845	5.027281906	0.035875961
Residual	21	4142.135246	197.2445355		
Total	22	5133.73913			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	58.54918033	5.68640218	10.29634881	1.15896E-09	46.72365963	70.37470103
Participation Rates-RLO's in SEM 2	9.668032787	4.311927946	2.242160098	0.035875961	0.700887733	18.63517784

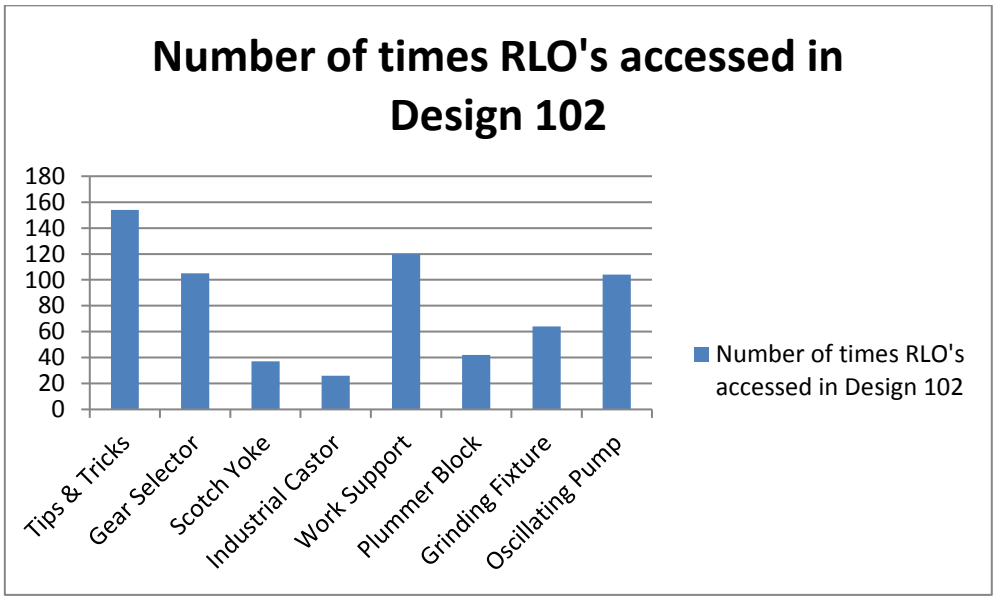
This result suggests that the students' participation rates of RLO's have had a positive effect on their grades achieved in the module Design 102 and justifies the importance of testing such relationships (Delialioglu and Yildirim 2007; Lopez *et al*. 2011). After further analysis the researcher also identified that during the module, Design 102, there was an increase in the amount of the times the RLO's were accessed, see Figure 3.5 and Figure 3.6, which may also have influenced this significant finding.

Figure 3.5



Access rates of RLO's in Design 101

Figure 3.6



Access rates of RLO's in Design 102

Through the statistical tool in moodle the amount of the times the RLO's were accessed was also analysed based on the individual exercises, see Table 3.14 and Table 3.15. There was a 38 per cent mean increase, Design 101 (Mean- 53 per cent) and Design 102 (Mean- 85 per cent), between the access rates in both modules.

Table 3.14 RLO access rates in Design 101

Design 101													
	Tips & Tricks	Exercise 1	Base Block	Offset Bracket	Indexing Unit	Basic Sketching	Creating a Solidworks Drawing	Gear Bracket	Sector Bracket	Gauge Plate	Crane Hook	Swivel Plate	Machine Casting
Number of times RLO's accessed in Design 101	91	54	52	67	55	31	54	61	62	25	36	40	61
Semester Access Average	**53**												

Number of times the video resources were accessed per resource.

Table 3.15 RLO access rates in Design 102

Design 102								
	Tips & Tricks	Gear Selector	Scotch Yoke	Industrial Castor	Work Support	Plummer Block	Grinding Fixture	Oscillating Pump
Number of times RLO's accessed in Design 102	154	105	37	26	120	42	64	104
Semester Average	**85**							

The most accessed RLO across both modules was the “Tips & Tricks” section. This included a series of short demonstration videos, approximately 1-2 minutes in duration which highlighted different key features and shortcuts for this CAD software. This section was also commented on in the semi-structured interviews, which is discussed later in this section.

Through the data analysis of the RLO usage the researcher observed that certain RLO's had a higher access rate than other RLO's, which warranted the need to conduct further in-depth analysis to evaluate the outcome of this trend. The RLO "Work Support" from Design 102 was selected based on the high usage rate in comparison to any other RLO.

Work Support

This RLO was accessed 120 times by the students, see Table 3.15. The grades achieved by both the control group and experimental group in this particular exercise were collected and analysed to determine if there was any statistical difference between the two groups.

H12$_0$. The access rates of the RLO's had no significant difference in the grades achieved in the exercise "Work Support": $\mu_0 = \mu_a$

H12$_a$. The access rates of the RLO's had a significant difference in the grades achieved in the exercise "Work Support": $\mu_0 \neq \mu_a$

The *t* test two-sample assuming unequal variances, see Table 3.16, shows there was a significant difference in the end of term exam grades, $p= 0.047 < 0.05$, therefore at a 0.05 level of significance, the Null Hypothesis **H12$_0$** can be rejected and **H12$_a$** is accepted. Therefore, there is sufficient statistical evidence to suggest that the access rates of the RLO's had a significant impact on the grades achieved in the exercise "Work Support". Furthermore, the magnitude of the difference in the means was moderate at $d = 0.46$, further supporting the significance of the finding.

Table 3.16 Comparison of grades in the exercise "Work Support"

Work Support Exercise		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 Work Support Average Grade	*2015/2016 Work Support Average Grade*
Mean	7.473684211	8.487804878
Variance	5.810099573	4.056097561
Observations	38	41
Hypothesized Mean Difference	0	
df	72	
t Stat	-2.020872258	
P(T<=t) one-tail	0.023506245	
t Critical one-tail	1.666293696	
P(T<=t) two-tail	0.047012489	
t Critical two-tail	1.993463567	
Decision	Reject null hypothesis	

This finding further supports the significance of the RLO's in improving academic grades, which could be contributed to the RLO's main role to support students' efforts rather than using a blended approach for delivering content only (Tamim *et al*. 2011). This is similar to what Schmid *et al*. (2009, p.97) refers to as a "support for cognition" rather than "presentation of content". The findings may also suggest that the RLO's improve academic grades if they are accessed more frequently. This adds to some of the limitations of this study and to comments from an interview of a student. The students were under no obligations to access these resources other than their aspirations to further reinforce their knowledge if they required. The next section examines the main themes from the interviews.

3.2.4.6. Sub-Research Question 6.

RQ.6. What were the attitudes of the students in relation to their blended learning experience?

The interviews were used as a means of gathering data to meet one of the research objectives and answer the sub-research question. The student responses were analysed based around their learning, quality and engagement of the blended approach, as identified in the literature. The students perceived this approach as a method which gave them a chance to further

develop their knowledge and skills in the area of design outside of the class, allowing them to study at their own pace and enhance their learning, which was reflected in their comments. The general consensus was that the RLO's were pitched at the right level (Windle *et al*. 2011), *"nice pace to the videos that were easy to follow"* (Student B3), contained material that was designed for the specific applications at hand (Parrish 2004), *" ideal for working on our exercises"* (Student D7), which helped achieve the intended learning outcomes and supported the students learning (Littlejohn *et al*. 2008), *" the RLO's seemed to make things simpler and easy to understand"* (C1).

According to the students the RLO's were of good quality in terms of visual and sound effects and their duration, which is generally referred to as granularity, was perfect. The RLO's were small to be usable (Littlejohn *et al*. 2008. p.738) but large enough "to provide a coherent learning experience" (Kendall *et al*. 2007. p.54). They liked the way the RLO's were *"broken down into chapters"* (B3) *"the use of two or three smaller videos was well done"* (C1).

The nature of the RLO's, linked to the module exercises enabled the students to be engaged throughout, in an interactive manner as they worked through each stage. In terms of their motivation, it was clear in the quantitative data that students with previous experience of CAD did not access the RLO's frequently. It would be biased to assume that based on this result they were not motivated by this blended approach. However, Student (C5) who had previous experience and did access the RLO's occasionally commented that while he felt the RLO's were a great asset, there was no requirement for him to make use of them. This is an aspect that would require further research going forward. Should there be some form of incentive in the form of assessment or self-assessment linked to the access of the RLO's? In a similar study (Windle *et al.* 2011), the students were shown to favour the use of self-assessment as a media tool. Student (C5) did comment that he now wishes he had of *"made more use of the videos as my result wasn't very good" (C5).*

The remaining five students that were interviewed, all of which had no previous experience were very engaged and motivated by this approach. They all commented on how they relied on the RLO's throughout the modules and would *"definitely"* recommend this approach to other students. Another common theme was in their belief that they will access these RLO's throughout their study to *"refresh on the basics before September"* (D6), *"100 per cent look at the videos, to go back over the material again"* (D7).

The emergent themes are highlighted in the three sections of the interview questions (a) Experience (b) Usage and (c) Recommendations.

Experience

The questions in this section aimed to determine how the students felt about their blended learning experience and if the RLO's assisted them in their studies. Several students reported that the blended learning experience provided them with extra resources outside of the class. As noted previously, 56 per cent of the students had no previous experience of using CAD software, so there were a number of students that had limited confidence in their ability to use this software. This feeling was expressed by student (D7), who commented that, *"At the start of the course I was struggling to understand how to use SolidWorks, while those next to me were flying along"*. The students that studied Design and Communications Graphics in Post-Primary education had an advantage over these students, with nearly a year of experience in using SolidWorks. Student (D7) further commented that *"the videos were a great help to me in getting used to SolidWorks and getting the exercises complete".*

With regard to the use of the RLO's, it was apparent that they believed they helped them in their studies

> "*In class I always felt that I was falling behind the rest of the lads, as it moves at such a fast pace. These videos allowed me to work through the exercises at my own pace and from the comfort of my own room……I wish I had used them more in the first semester, maybe I wouldn't have failed." (C1)*

This student's belief is supported by an increase in their overall grades between Design 101 and Design 102, (29 per cent- 62 per cent), possibly contributed by the increase in their access rates of the RLO's. The student commented that in preparation for the repeat aspects for Design 101 he accessed the RLO's for the first time *"to get up to speed"* and only then realised the benefits of the RLO's. The student also recommended that future students should *"use the RLO's right from the start"*.

Student (B3) also commented on their use of the RLO's to further develop their knowledge in these modules outside of class time

> *"I would have struggled to pass the subject without the videos. I found it hard to get the exercises finished during the three hours of class. The videos allowed me to catch up with the work in my own time" (B3)*

These comments reinforce the benefits of a blended approach, the flexibility of actively engaging in their studies outside of the class (Sharpe *et al*. 2006; Sjoer and Dopper 2006; Smyth 2012), which also reinforces the student's autonomy (Lopez *et al*. 2011). The use of the RLO's assisted the students in completing their exercises, which reinforces the increase in their continuous assessment grades (LaMeres and Plumb 2014).

Usage

The questions in this section aimed to determine the students perceptions of the RLO's, in terms of their quality, in relation to their content, visual and sound effects and their reusability features including video duration and their likelihood to access these videos at a later stage in their study. The questions also gauged whether they found the RLOs engaging. All students agreed that the content of the RLO's was at a suitable level, with two students commenting that the highlighting of "*key points"* in the videos helped them prepare for the exam.

> *"I found the videos useful for revision prior to the exam to remember parts that I didn't understand fully in the class" (C5)*

The main aspect of the moodle page that was discussed by the majority of the students was the "Tips and Tricks" section, which contained these "*key points"*.

> " *The section with the short video clips that showed stuff like putting a thread on a part was very useful, especially when it came to doing the drawings, as I always forgot how to do it or missed that part when it was shown in class" (D6)*

A key aspect of LO's is there accessibility and usability. The students were all satisfied with the quality of the RLO's in term of their content, *"They were very easy to follow. I really liked how time was spent at the start explaining where to locate the origin*" (B3), duration, *"The duration of the RLO's was ideal. Some exercises I played back four or five times as it was so easy to keep going back"* (D6) and usability, *"For each exercise there was three or four short videos, which was great. It was very easy to pause and go back again or even skip forward to where you wanted to be"* (C1).

The RLO's were not implemented to replace the expertise and guidance of the lecturer, however, these comments suggest that RLO's "can, and do, provide an unrestricted virtual form of assistance to the student learner when they need it" (Gee *et al*. 2014, p.12).

Recommendations

The main aim of the questions in this section was to determine if the students would recommend using RLO's as a form of learning and get their opinions on replacing face-to-face instruction completely with blended learning. In relation to their responses to the future of face-to-face instruction, a number of students struggled to understand the concept of the question. This question posed no problems during the pilot study, however, it is now apparent to the researcher that the students from the pilot study were mature students and the level of the question was at a more suitable level for their age range. However, after some further explanations the students were able to give their opinions. The common view of the students was that blended learning should not totally replace face-to-face learning as

> *"face-to-face learning allows you to ask questions in person when you get into difficulty, however, blended learning gives a great balance of both"(C1)*

Student (D7) also believed that *"you can't beat been able to ask questions in class"* and saw the blended approach as a means of *"back up".* A similar response evident in other studies (Lopez *et al*. 2011; Williams *et al*. 2015), which further justifies the use of technological tools to complement face-to-face teaching. Student (D6) made an interesting comment into how it *"would depend on the individual student"* in relation to those that had previous experience with CAD.

3.5. Conclusion

Overall, this blended learning approach was viewed very positively by the students that were interviewed, a similar finding to many other studies that adopt this approach to support traditional teaching (Cortizo *et al*. 2010; Sharpe *et al*. 2006; Williams *et al*. 2015). The RLO's were viewed as a means of reinforcing their understanding of material covered in class, which would have a positive effect on their learning (Lei 2010). Furthermore, the students noted that they would recommend this approach, however they were adamant that blended learning should not replace face-to-face instruction, highlighting the importance of maintaining personal interaction between students and teachers. Their satisfaction with this approach could be seen as an indicator of the quality of learning, a view also supported by (Lopez *et al*. 2011).

Section Four: Conclusion

4.1. Conclusion

In this study, a comparison of blended learning with traditional classroom delivery in an undergraduate engineering module, in terms of academic achievement and student perceptions is investigated. This study implemented the use of RLO's as a blended learning tool to supplement traditional approaches in teaching design modules in which student diversity; students' prior knowledge of design and the creative nature of CAD make it difficult to facilitate learning.

While the study has shown that there was no statistical difference in the mean of the overall grades between both groups across both modules, further in-depth analysis suggested that there was sufficient statistical evidence to suggest that the blended learning approach had a significant impact on the students' end of term exam grades in the module Design 102. Furthermore, a small to moderate effect size of 0.37, was determined. This finding was also supported by a significant positive relationship between the students' RLO usage and their end of term exam grades in Design 102. These findings indicate that students' academic grades are likely to increase with an increased uptake in the usage of the RLO's. The study also highlighted that students with no previous experience of CAD have a higher usage rate of the RLO's, an important finding, as the aim of this implementation was to target those with no previous experience of CAD. In addition to these findings, the mixed method approach used in the study reveals some of the benefits that the students experienced from blended learning, mainly flexibility and reusability (Ireland *et al*. 2009; Smyth *et al*. 2012) of the RLO's. According to the students, the design of the RLO's was very suitable and they were satisfied with the granularity and context of the RLO's. Some minor issues around the utilisation were evident and warrant further investigation.

A positive outcome from the researchers' perspective is that the RLO's were used as the researcher intended, a technological based intervention to help emphasis difficult concepts (Dutil *et al*. 2015) in these design modules. Student perceptions of this approach were very positive, however, students that were interviewed were keen to emphasise that blended learning should not totally replace face-to-face teaching, similar findings as (Poon 2011; Waha and Davis 2014; Wong *et al*. 2013). However, it should be remembered that these

cohort of students are familiar with traditional teaching approaches and new to the medium of blended learning, which may have influenced their decision. Overall this study has shown that using RLO's as a blended learning tool, used to supplement didactic traditional classroom teaching, can enhance student learning in a more efficient manner than students taught in a face-to-face learning environment. Furthermore, this study has addressed some of the challenges associated with RLO's, discussed in the literature review, and helped fill the gaps in the literature in relation to the adoption of RLO's as a blended learning tool in teaching CAD.

4.2. Research Limitations

This research study is primarily limited with the small sample size, which may limit the generalisability of the findings. Furthermore, the use of purposive sampling as a selection process may have led to a biased sample group. The researcher also acknowledges that there were other variables that may have been considered such as student demographic characteristics (Mersal and Mersal 2014) including students age, gender, although this study consisted of all male students, and the students confidence with the technology (Demirer and Sahin 2013). The research may also have benefitted in comparing other previous cohorts of students, however as their mean CAO points were significantly different, this would have affected the validity of the study.

In relation to the RLO's, the researcher, supported by a comment from a student feels that there should have been some sort of incentive for students to access the RLO's. This may be in the form of exercises to be completed by the following lab, peer review or self-assessment as mentioned previously.

4.3. Suggestions for Further Research

This intervention was the first step to a broader adoption of blended learning in the area of design within the Mechanical & Electronic engineering department in IT Sligo. Based on the outcome of this study, the researcher would be recommending that the use of RLO's be adopted across a range of modules and made available through a repository within the IOT's. If this was to occur, further research would be required to examine their effects across different IOT's. While this study has shown its positive effects, factors including the willingness of academic staff to adopt this approach and commit to the workload involved in implementing it also need to be considered. Blended learning is seen to be a cost-effective approach for HEI's. While some studies have examined these costs, there is no available

research on the cost-effectiveness of implementing RLO's as a blended learning tool. These costings would need to consider the design, development and monitoring the usage of these resources. These design modules may be more suited to the implementation of RLO's, therefore, a similar blended approach, using RLO's, should be employed across other modules and compare the findings of those studies with this study.

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Appendix A: Critiquing the Literature

Student Academic Achievement

Author/Area	Methodology	Findings	Limitations
Cosgrove and Olitsky (2015) *'Knowledge Retention, Student Learning, and Blended Course Work: Evidence from Principles of Economics Courses,*	Experimental study using control and experimental group. Comparing performance on assessment. N= 429	Results suggest that while there is no significant difference in student learning, students in more traditional, technology-free courses retain the material better than students.	The sample used is not representative of the population of college students, so the results are not generalizable. The test data collected was limited to 10 questions.
Castano *et al*. (2014) *"The Internet in face-to-face higher education: Can interactive learning improve academic achievement?"*	Comparative study of online and traditional face-to-face delivery using control and experimental groups. Duration-16 weeks. Online questionnaires and analysis of academic performance. N= 8046-across 3 universities	The time spent studying online is only useful when it takes place as some form of interactive learning. Using the Internet as a space where academic information can be posted or where students can actively search for complementary information is not shown to be an effective strategy for improving learning.	Student usage of this approach was measured, based on participants' responses to a questionnaire and not on direct data.
Gee (2014) *"The Role of Reusable Learning Objects in Occupational Therapy Entry-Level Education"*	Mixed Methods approach using Online survey and two focus groups (n=8; 4 students per group) and Analysis of academic performance Duration- ? N=15	The use of RLOs may reduce the time spent reviewing materials and teaching foundational skills, and allow educators to use their expertise on the advanced content and skills necessary for generalist entry-level practice.	Very small sample size in the use of surveys leading to insufficient data. Also ANOVA test not supported with effect size.
LaMeres and Plumb (2014) *"Comparing Online*	Comparative study of online and traditional face-to-face delivery	The findings showed there was no noticeable difference between the two	The study failed to highlight the sample population and the sample selection

to Face-to-Face Delivery of Undergraduate Digital Circuits Content"	using control and experimental groups in an undergraduate digital systems module. Mixed method approach. Duration-16 weeks. Survey and analysis of academic performance. N= 391	delivery approaches.	method.
Author/Area	**Methodology**	**Findings**	**Limitations**
Mersal and Mersal (2014) "*Effect of Blended Learning on Newly Nursing Student's Outcomes Regarding New Trends in Nursing Subject at Ain Shams University"*	A quasi experimental study of online and traditional face-to-face delivery using control and experimental groups. Mixed method approach. Questionnaires and analysis of academic performance.	Findings indicate improvement regarding satisfactory level of achievement of blended learning group, however with no statistical difference between two groups. High satisfaction level.	
Francis and Shannon (2013) *'Engaging with blended learning to improve students' learning outcomes'*	Two longitudinal case studies using qualitative research methods. Duration- 4 years	That engineering students learning is advantaged in studio-based subjects containing dense technical material by the adoption of best-practice blended learning. Also that students who do not engage with blended learning are academically disadvantaged	The study has a number of limitations including it failed to highlight the sample population and the sample selection method. It stated it is based on qualitative, however it is clearly quantitative. Also ANOVA test not supported with effect size.
Stuart, A (2013) '*Engaging Student's Learning Through a Blended Learning Environment'*	Findings based on an action research study. Duration- 12 weeks. Mixed method approach. Observation, questionnaires and	The use of RLO's and other eLearning resources enhanced the students' learning experience.	The study failed to highlight the sample population and the sample selection method.

	semi-structured interviews. N=		
Author/Area	**Methodology**	**Findings**	**Limitations**
Wong *et al.* (2013) *'A framework for investigating blended learning effectiveness'*	Case study (Survey) involving the assessment of a blended learning approach to the delivery of a first-year undergraduate course.	Despite different options available there was strong support for face-to-face delivery methods.	
Poon, J (2012) *'An examination of a blended learning approach in the teaching of economics to property and construction students'*	Case study approach using evaluation questionnaires. N= 82	Students found that the blended learning approach through the use of the Virtual Learning Environment was integrated well and it enhanced their overall learning experience	One limitation of this paper is that it only reports on one cycle of evaluation of the concerned module. A suggestion for future research is to conduct an action research study of the PCE module
Alonso *et al.* (2011) *"How Blended Learning Reduces Underachievement in Higher Education: An Experience in Teaching Computer Sciences"*	Comparative study of online and traditional face-to-face delivery using control and experimental groups. Comparison of grades. Duration- 15 weeks N= 693	Findings reveal that it is possible to reduce underachievement in higher education through an adequate use of e-learning technology, supported by a moderate constructivist instructional model and a blended learning approach. The mean grade for students receiving blended learning is statistically greater than the mean grade achieved by students receiving traditional tuition in previous years.	
Mahnken *et al*. (2011) *"Blended learning in radiology: Is self-determined learning really more*	Comparative study of online and traditional face-to-face delivery using control and experimental groups-randomly assigned.	There was a trend towards a higher improvement in knowledge in students exposed to a blended learning approach, however	Study didn't consider students perceptions of the approach. Duration of study too short.

effective?"	Duration- 1 week Analysis of academic performance using pre and post tests. N= 96	with no statistical difference between two groups.	
Author/Area	**Methodology**	**Findings**	**Limitations**
Lopez *et al.* (2011) *'Blended learning in higher education: Students perceptions and their relation to outcomes'.*	Findings based on secondary data a questionnaire. N= 985	Blended learning has a positive effect in improving retention rates and in improving academic performance.	Did not consider the degree of utilisation of the blended learning tools.
Poon, J (2011) *'Use of blended learning to enhance the student learning experience and engagement in property education'*	Mixed method approach. Findings based on telephone interviews and questionnaire surveys. Use of VLE. N= 442	Blended learning can improve students' learning experience and offers greater flexibility in terms of learning style and study pace. Face-to-face interaction" with students is important as students require reassurance and on-going support from lecturers.	Author does not highlight what form of blended learning approaches were adopted
Vernadikis *et al*. (2011) *"Comparing hybrid learning with traditional approaches on learning the Microsoft Office Power Point 2003 program in tertiary education"*	Comparative study between bended course and traditional course Duration- 16 weeks. N=69	Blended courses produce a stronger sense of community among students than either traditional or fully online courses.	The researchers exercised no experimental control over the courses examined in the present study and cause-and-effect relationships were not confirmed.
Windle *et al*. (2011) *'The characteristics of reusable learning objects that enhance learning: A case-study in health-science education'*	Case Study, Evaluation forms and questionnaires. N=118	That RLOs can be an effective and popular educational intervention within an aspect of the curriculum that students traditionally find difficult	A wider evaluation is required to fully appreciate the significance of the reuse potential of the resources used.

Author/Area	Methodology	Findings	Limitations
Cortizo *et al*. (2010) *"Blended learning applied to the study of Mechanical Couplings in engineering"*	Experimental study involving comparison of control and experimental group using pre and post-tests. Duration- ? N=30	Blended learning approach, increased the level of knowledge of the students in the experimental group, since they obtained a higher average mark in the validated test. Moreover, it was shown to raise the knowledge of all students.	The study failed to highlight sample selection method. Also independent *t* test not supported with effect size.
Gonzalez *et al*. (2010) *"A web-based learning tool improves student performance in statistics: A randomized masked trial"*	Experimental study involving comparison of control and experimental group Duration- 35 hours. Comparing grade difference in final exam. N= 121	Web based learning has a positive effect on student performance and that it is feasible to evaluate learning interventions with formal experiments	Study does not consider variables that may influence the study including prior knowledge, student demographics.
Sahin and Demirer (2009) *'Effect of blended learning environment on transfer of learning: an experimental study'*	A 14-week experimental study using two randomly assigned groups in the model, the experimental group and the control group. Evaluated academic achievement and transfer of learning. N= 44	Blended learning environments provide not only an alternative way of learning of a subject matter, but also an effective approach of putting the course content into practice.	This study is administered within the period of a semester to a small group of students who do not have previous exposure to blended learning. Other possible confounding variables associated with learning outcomes, such as time on task, motivation, access, or technology confidence, were not assessed in the study.

Student Perceptions

Author/Area	Methodology	Findings	Limitations
Dutil *et al*. (2015) *"Introduction of Reusable Learning Objects in a First Year Materials Science and Engineering Course"*	Online survey Duration- ? N=118	RLOs were found to be an effective and engaging method for supplementing core didactic teaching. User opinions and preferences are valuable data that should be taken into account when choosing to include interventions in the curriculum.	Insufficient analysis of limited quantitative data. Also ANOVA test not supported with effect size.
Waha and Davis (2014) *"University students' perspective on blended learning"*	Online survey Quan/Qual analysis N=23- Masters students	Students like the flexibility and the convenience of online learning, but also the possibilities that derive from face-to-face interaction with teachers and peers for building personal learning networks. Blended learning is an approach that supports a range of learning styles and life styles.	Insufficient analysis of limited quantitative data.
Wong *et al*. (2013) *"A framework for investigating blended learning effectiveness"*	Case study using a survey of first year undergrads. Duration- 4 semesters N= 515	Despite having three new online options readily available for students to access, there was strong support for face-to-face delivery methods. The impact of the blended learning approach is considered during its design rather than as an afterthought after implementation.	The framework focused primarily on the intensity of adoption and impact of blended learning and could have considered the assessment of student's evaluation of the overall blended learning suite of offerings
Smyth *et al*. (2012) *"Students'*	Qualitative interpretive descriptive design	A significant finding that was not reported in previous research	The focus groups were conducted six months from the end of their

experiences of blended learning across a range of postgraduate programmes."	was used. Focus groups were used to collect the data using semi-structured interviews. Duration- N= 51	was that the online component meant little time away from study for the students suggesting that it was more invasive on their everyday life.	programme; hence the full experiences may not have been captured.
Author/Area	**Methodology**	**Findings**	**Limitations**
Wu *et al*. (2010) *"A study of student satisfaction in a blended e-learning system environment"*	Research model that was based on social cognitive theory for investigating the key determinants of student learning satisfaction in a blended learning environment. Mixed method approach. Questionnaires and interviews N= 212	The findings indicate that computer self-efficacy, performance expectations, system functionality, content feature, interaction, and learning climate are the primary determinants of student learning satisfaction with a blended learning system.	Self-report measures were not recognized when interpreting the results.
Delialioglu and Yildirim (2007) *"Students' Perceptions on Effective Dimensions of Interactive Learning in a Blended Learning Environment"*	Case Study. Qualitative and quantitative data analysis using interview and monitoring of student usage. Duration- 14 weeks N= 25	The findings showed that metacognitive support, authentic learning activities, collaboration, type and source of motivation, individualized learning, and access to the Internet played important roles in students' learning in the hybrid course.	Insufficient analysis of limited quantitative data.

Appendix B: Research Information Sheet for Students from 2015/2016 Academic Year

INFORMATION SHEET

Title of Study: An investigation into the effectiveness of Reusable Learning Objects as a blended learning tool in an undergraduate engineering design module.

Name of Principal Investigator: Paul Ferry, Assistant Lecturer in the Department of Mechanical & Electronic Engineering.

You are being invited to participate in a research study. Thank you for taking time to read this.

What is the purpose of this study?

As part of the requirements for a Master of Arts in Learning, Teaching and Assessment that I'm pursuing through Letterkenny Institute of Technology, I wish to carry out a study. The study is concerned with examining the effectiveness of adopting a blended learning approach in an undergraduate engineering module. I want to examine the effectiveness of this intervention by comparing the results of two groups of students: this year's group of students, who are involved in the blended learning approach and a previous year group of students who were taught using traditional methods only.

Are you 18 years of age?

If you are not over 18 years of age then your data will not be considered for this study. You still have access to all the available resources that are part of this intervention. You do not have to continue with this consent form. Thank you for your time.

Description of the Study Procedures

This intervention aims to provide students with additional learning support in the module Design 101/102, by allowing them to access pre-lab activities and reusable learning objects

from a dedicated moodle page. If you agree to be in this study then you will be asked to do the following things:

- Complete the enclosed consent form.
- Allow the researcher to have access to your CAO entry level points into this course.
- Allow the researcher access to have access to the continuous assessment grades achieved in the module Design 101/102.
- Allow the researcher to interview you about your experience in this blended learning approach.

Why have you been chosen? You have been chosen because this study is focusing on the modules Design 101/102 and you are currently studying in these modules.

Are there any benefits in participating in this study?

You have access to the resources in this intervention regardless if you do or do not take part in the study. However in order to establish whether this intervention is effective and can be used for future students and adopted in similar modules, data is required.

Are there any risks or discomforts in being involved in this study?

As part of this study you will be asked to allow the researcher to use the results you obtained in the Design 101/102 modules as research data that will be analysed. There are no reasonable expected risks involved in this study.

What happens if you refuse to participate?

Your participation in this study is entirely voluntary. If you decide not to take part in this study your rights will not be affected in any way. If you decide to take part you may still withdraw at any time throughout the study and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will also not affect your rights in any way.

Will your participation in this study be kept confidential?

Yes, this study will be anonymous. Your identity throughout the study will remain confidential. You will be identified by a study number, e.g. A1 ensuring that your name will not be published or disclosed to anyone.

What will happen to the information which you give?

The data recorded for this study will be kept strictly confidential for the duration of the study. All research data will be kept in a secure location for a further 5 years and then destroyed.

What will happen to the results?

The results from the study will be presented in the thesis. They will be seen by my supervisor, a second marker and an external examiner. The thesis may possibly be read by other people with an interest in this field.

Will I be paid for participating in this study?

No.

Has this study been reviewed by an Ethics committee?

The Research Ethics committee at Letterkenny Institute of Technology have reviewed this study.

Who can I contact if I have any questions or concerns about this study?

You have the right to ask any questions you may have about this research study and have your questions answered by me at any time before, during or after the research. If you would like any further information about the study, at any time please contact me: Paul Ferry at ferry.paul@itsligo.ie or by telephone at 0719155276.

If you agree to take part in the study, please sign the consent form attached.

Appendix C: Research Information Sheet for Students from 2014/2015

Academic Year

Title of Study: An investigation into the effectiveness of Reusable Learning Objects as a blended learning tool in an undergraduate engineering design module.
Name of Principal Investigator: Paul Ferry, Lecturer in the Department of Mechanical & Electronic Engineering.

You are being invited to participate in a research study. Thank you for taking time to read this.

What is the purpose of this study?

As part of the requirements for a Master of Arts in Learning, Teaching and Assessment that I'm pursuing through LYIT, I wish to carry out a study. The study is concerned with examining the effectiveness of adopting a blended learning approach in an undergraduate engineering module. I want to examine the effectiveness of this intervention by comparing the results of two groups of students: this year's group of students, who are involved in the blended learning approach and a previous year group of students who were taught using traditional methods only.

Are you 18 years of age?
If you are not over 18 years of age then your data will not be considered for this study. You still have access to all the available resources that are part of this intervention. You do not have to continue with this consent form. Thank you for your time.

Description of the Study Procedures

This intervention aims to provide students with additional learning support in the module Design 101/102, by allowing them to access pre-lab activities and reusable learning objects from a dedicated moodle page. If you agree to be in this study then you will be asked to do the following things:

- Complete the enclosed consent form.
- Allow the researcher to have access to your CAO entry level points into this course.

- Allow the researcher access to have access to the grades you achieved in the module Design 101/102 for the academic year 2014/2015.

Why have you been chosen? You have been chosen because this study is focusing on the modules Design 101/102 and you studied these modules in the 2014/2015 year .

Are there any benefits in participating in this study?

You do not benefit from this study. However in order to establish whether this intervention is effective and can be used for future students and adopted in similar modules, data is required.

Are there any risks or discomforts in being involved in this study?

As part of this study you will be asked to allow the researcher to use the results you obtained in the Design 101/102 modules as research data that will be analysed. There are no reasonable expected risks involved in this study.

What happens if you refuse to participate?

Your participation in this study is entirely voluntary. If you decide not to take part in this study your rights will not be affected in any way. If you decide to take part you may still withdraw at any time throughout the study and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will also not affect your rights in any way.

Will your participation in this study be kept confidential?

Yes, this study will be anonymous. Your identity throughout the study will remain confidential. You will be identified by a study number, e.g. A1 ensuring that your name will not be published or disclosed to anyone.

What will happen to the information which you give?

The data recorded for this study will be kept strictly confidential for the duration of the

study. All research data will be kept in a secure location for a further 5 years and then destroyed.

What will happen to the results?

The results from the study will be presented in the thesis. They will be seen by my supervisor, a second marker and an external examiner. The thesis may possibly be read by other people with an interest in this field.

Will I be paid for participating in this study?

No.

Has this study been reviewed by an Ethics committee?

The Research Ethics committee at Letterkenny Institute of Technology have reviewed this study.

Who can I contact if I have any questions or concerns about this study?

You have the right to ask any questions you may have about this research study and have your questions answered by me at any time before, during or after the research. If you would like any further information about the study, at any time please contact me: Paul Ferry at ferry.paul@itsligo.ie or by telephone at 0719155276.

If you agree to take part in the study, please sign the consent form overleaf.

Appendix D: Research Consent Form

PARTICIPANT CONSENT FORM

Project Title: An investigation into the effectiveness of Reusable Learning Objects as a blended learning tool in an undergraduate engineering design module.

Principal Investigator: Paul Ferry

Participant Declaration:

Tick Yes or No as appropriate:

1. I confirm that I have received a copy of the Information Sheet for the above study. I have read it or had the information sheet read to me and I understand it.

   Yes ☐ No ☐

2. I have received an explanation of the nature, purpose, duration and foreseeable effects and risks of the study and what my involvement will be.

   Yes ☐ No ☐

3. I have had time to consider whether to take part in this study and I have been given an opportunity to ask questions and am satisfied with the answers.

   Yes ☐ No ☐

4. I understand that my participation is voluntary and that I can withdraw at any time, without giving any reason and will not affect my rights.

   Yes ☐ No ☐

5. I consent to be part of this study.

   Yes ☐ No ☐

6. I consent to allow the data obtained to be used in other future studies without the need for additional consent.

   Yes ☐ No ☐

Participants Name (Block Capitals):

Contact Details:

Date:

Signature of the Participant:

Researchers Name (Block Capitals):

Date:

Signature of the Researcher:

Appendix E: Research Interview Questions

PARTICIPANT INTERVIEW FORM

Title of Study: An investigation into the effectiveness of Reusable Learning Objects as a blended learning tool in an undergraduate engineering design module.

Name of Principal Investigator: Paul Ferry, Assistant Lecturer in the Department of Mechanical & Electronic Engineering.

The student interview questions were adapted from questions sourced in the literature surrounding blended learning (Garrison and Vaughan 2008; Krauss and Ally 2005; Poon 2012; Williams *et al*. 2015; Windle *et al.* 2011). The interview questions are divided into three sections. The first section queries the students' experience of blended learning. The second section looks into the students' usage of the RLO's. The final section asks students for recommendations or changes that they feel would improve the experience.

Experience

1. How did you find this blended learning approach?
2. Do you think the use of RLO's as a blended learning tool has helped or hindered your studies? And how?
3. What worked well in using this blended learning approach?
4. What didn't work well in using this blended learning approach?

Usage

5. Did you find the content of the RLO's was at a suitable level? Why, or why not?
6. Do you think the design of the RLO's was suitable in terms of the visual and sound effects? Why, or why not?
7. How did you find the reusability features of these RLO's, was the video duration suitable?
8. Do you think you will access these RLO's again throughout your study? Why, or why not?

Recommendations

9. Would you recommend the use of RLO's to other students? Why, or why not?
10. In your opinion, do you think blended learning could totally replace "face-to-face" interactions? Why, or why not?

Appendix F: Independent T-Tests & Cohen's *d* test

Hypothesis 1: Is there a significant difference in the overall grades between the experimental group and the control group in Design 101.

Module- Design 101		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 Overall Grade Design 101	*2015/2016 Overall Grade Design 101*
Mean	62.93421053	67.20363918
Variance	257.8671764	335.2883649
Observations	38	41
Hypothesized Mean Difference	0	
df	77	
t Stat	-1.103696424	
P(T<=t) one-tail	0.136581077	
t Critical one-tail	1.664884537	
P(T<=t) two-tail	0.273162155	
t Critical two-tail	1.991254395	
Decision	Do not reject null hypothesis	

Cohen's *d* test: Effect Size

	n	**Mean**	**Standard Dev.**
2015/2016 Overall Grade Design 101	*41*	*67.203*	18.53358951
2014/2015 Overall Grade Design 101	38	*62.934*	16.05824325
Mean Difference		4.269	
Pooled SD		17.29592	
Cohen's *d*		0.246821	
Small		0.2	
Medium		0.5	
Large		0.8	

Hypothesis 2: Is there a significant difference in the overall grades between the experimental group and the control group in Design 102.

Module- Design 102		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 Overall Grade Design 102	*2015/2016 Overall Grade Design 102*
Mean	61.61842105	67.41943829
Variance	203.4793975	238.543227
Observations	38	41
Hypothesized Mean Difference	0	
df	77	
t Stat	-1.746253159	
P(T<=t) one-tail	0.042351993	
t Critical one-tail	1.664624645	
P(T<=t) two-tail	0.084703987	
t Critical two-tail	1.990847069	
Decision	Do not reject null hypothesis	

Cohen's *d* test: Effect Size

	n	**Mean**	**Standard Dev.**
2015/2016 Overall Grade Design 102	*41*	*67.419*	15.5472663
2014/2015 Overall Grade Design 102	38	*61.618*	14.45610047
Mean Difference		5.801	
Pooled SD		15.00168	
Cohen's *d*		0.38669	
Small		0.2	
Medium		0.5	
Large		0.8	

Hypothesis 3: Is there a significant difference in the continuous assessment grades between the experimental group and the control group in Design 101.

Module- Design 101		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 CA Grade Design 101	*2015/2016 CA Grade Design 101*
Mean	64.69996129	70.68421053
Variance	349.4530336	196.059744
Observations	38	41
Hypothesized Mean Difference	0	
df	74	
t Stat	-1.617795361	
P(T<=t) one-tail	0.054980852	
t Critical one-tail	1.665706893	
P(T<=t) two-tail	0.109961704	
t Critical two-tail	1.992543495	
Decision	Do not reject null hypothesis	

Cohen's *d* test: Effect Size

	n	**Mean**	**Standard Dev.**
2015/2016 CA Grade Design 101	*41*	*70.684*	18.87002158
2014/2015 CA Grade Design 101	38	*64.699*	13.54776598
Mean Difference		5.985	
Pooled SD		16.20889	
Cohen's *d*		0.369242	
Small		0.2	
Medium		0.5	
Large		0.8	

Hypothesis 4: Is there a significant difference in the continuous assessment grades between the experimental group and the control group in Design 102.

Module- Design 102		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 CA Grade Design 102	*2015/2016 CA Grade Design 102*
Mean	57.05263158	61.32668145
Variance	282.4295875	390.588614
Observations	38	41
Hypothesized Mean Difference	0	
df	76	
t Stat	-1.037864432	
P(T<=t) one-tail	0.151312009	
t Critical one-tail	1.665151353	
P(T<=t) two-tail	0.302624017	
t Critical two-tail	1.99167261	
Decision	Do not reject null hypothesis	

Cohen's *d* test: Effect Size

	n	**Mean**	**Standard Dev.**
2015/2016 CA Grade Design 102	*41*	*61.326*	19.80895273
2014/2015 CA Grade Design 102	38	*57.052*	16.80564154
Mean Difference		4.274	
Pooled SD		18.3073	
Cohen's *d*		0.233459	
Small		0.2	
Medium		0.5	
Large		0.8	

Hypothesis 5: Is there a significant difference in the end of term exam grades between the experimental group and the control group in Design 101.

Module- Design 101		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 End of Term Exam Grade Design 101	*2015/2016 End of Term Exam Grade Design 101*
Mean	63.71052632	69.70731707
Variance	512.3193457	485.9621951
Observations	38	41
Hypothesized Mean Difference	0	
df	76	
t Stat	-1.191406446	
P(T<=t) one-tail	0.118600741	
t Critical one-tail	1.665151353	
P(T<=t) two-tail	0.237201481	
t Critical two-tail	1.99167261	
Decision	Do not reject null hypothesis	

Cohen's *d* test: Effect Size

	n	**Mean**	**Standard Dev.**
2015/2016 End of Term Exam Grade Design 101	*41*	*69.707*	22.32366802
2014/2015 End of Term Exam Grade Design 101	38	*63.71*	22.63447251
Mean Difference		5.997	
Pooled SD		22.47907	
Cohen's *d*		0.266781	
Small		0.2	
Medium		0.5	
Large		0.8	

Hypothesis 6: Is there a significant difference in the end of term exam grades between the experimental group and the control group in Design 102.

Module- Design 102		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 End of Term Exam Grade Design 102	*2015/2016 End of Term Exam Grade Design 102*
Mean	66.18421053	73.51219512
Variance	263.4516358	251.1060976
Observations	38	41
Hypothesized Mean Difference	0	
df	76	
t Stat	-2.027939139	
P(T<=t) one-tail	0.023035741	
t Critical one-tail	1.665151353	
P(T<=t) two-tail	0.046071482	
t Critical two-tail	1.99167261	
Decision	Reject null hypothesis	

Cohen's *d* test: Effect Size

	n	**Mean**	**Standard Dev.**
2015/2016 End of Term Exam Grade Design 102	*41*	*73.512*	16.03823556
2014/2015 End of Term Exam Grade Design 102	38	*66.184*	16.2311933
Mean Difference		7.328	
Pooled SD		16.13471	
Cohen's *d*		0.454176	
Small		0.2	
Medium		0.5	
Large		0.8	

Hypothesis 7: The students' previous experience of CAD has a significant difference in their participation rates of the RLO's.

F Test: Determining the equality of variance

F-Test Two-Sample for Variances		
	Participation Rates in RLO's With No Previous Experience	*Participation Rates in RLO's With Previous Experience*
Mean	1.782608696	0.944444444
Variance	0.996047431	1.467320261
Observations	23	18
df	22	17
F	0.678820744	
P(F<=f) one-tail	0.194502702	
F Critical one-tail	0.473088176	

t-Test: Two-Sample Assuming Equal Variances		
	Participation Rates in RLO's With No Previous Experience	*Participation Rates in RLO's With Previous Experience*
Mean	1.782608696	0.944444444
Variance	0.996047431	1.467320261
Observations	23	18
Pooled Variance	1.201474049	
Hypothesized Mean Difference	0	
df	39	
t Stat	2.429853995	
P(T<=t) one-tail	0.009904722	
t Critical one-tail	1.684875122	
P(T<=t) two-tail	0.019809444	
t Critical two-tail	2.02269092	
Decision	Reject null hypothesis	

Cohen's *d* test: Effect Size

	n	Mean	Standard Dev.
Participation Rates in RLO's With No Previous Experience	*23*	*1.783*	0.998
Participation Rates in RLO's With Previous Experience	18	*0.944*	1.211
Mean Difference		0.839	
Pooled SD		1.1045	
Cohen's *d*		0.75962	
Small		0.2	
Medium		0.5	
Large		0.8	

Hypothesis 11: Did the access rates of the RLO's have a significant difference in the grades achieved in the exercise "Offset Bracket"

Offset Bracket Exercise		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 Offset Bracket Average Grade	*2015/2016 Offset Bracket Average Grade*
Mean	6.921052632	7.536585366
Variance	4.453058321	5.004878049
Observations	38	41
Hypothesized Mean Difference	0	
df	77	
t Stat	-1.258403125	
P(T<=t) one-tail	0.106024166	
t Critical one-tail	1.664884537	
P(T<=t) two-tail	0.212048333	
t Critical two-tail	1.991254395	
Decision	Do not reject null hypothesis	

Cohen's *d* test: Effect Size

	n	**Mean**	**Standard Dev.**
2015/2016 Offset Bracket Average Grade	*41*	*7.536*	2.237158476
2014/2015 Offset Bracket Average Grade	38	*6.921*	2.110227078
Mean Difference		0.615	
Pooled SD		2.173692777	
Cohen's *d*		0.282928667	
Small		0.2	
Medium		0.5	
Large		0.8	

Hypothesis 12: Did the access rates of the RLO's have a significant difference in the grades achieved in the exercise "Work Support".

Work Support Exercise		
t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015 Work Support Average Grade	*2015/2016 Work Support Average Grade*
Mean	7.473684211	8.487804878
Variance	5.810099573	4.056097561
Observations	38	41
Hypothesized Mean Difference	0	
df	72	
t Stat	-2.020872258	
P(T<=t) one-tail	0.023506245	
t Critical one-tail	1.666293696	
P(T<=t) two-tail	0.047012489	
t Critical two-tail	1.993463567	
Decision	Reject null hypothesis	

Cohen's *d* test: Effect Size

	n	**Mean**	**Standard Dev.**
2015/2016 Work Support Average Grade	*41*	*8.488*	2.013975561
2014/2015 Work Support Average Grade	38	*7.473*	2.410414814
Mean Difference		1.015	
Pooled SD		2.212195187	
Cohen's *d*		0.458820273	
Small		0.2	
Medium		0.5	
Large		0.8	

Appendix G: Correlation Analysis

Hypothesis 8: Is there is a relationship between the students' RLO usage and their overall academic grades in Design 101.

Regression Statistics	
Multiple R	0.216057622
R Square	0.046680896
Adjusted R Square	0.001284748
Standard Error	16.99035669
Observations	23

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	296.8418811	296.84188	1.02830082	0.322099872
Residual	21	6062.116629	288.67222		
Total	22	6358.95851			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	55.76984127	6.006998215	9.2841448	6.9979E-09	43.27760462	68.2620779
Participation Rates-RLO's in SEM 1	7.542857143	7.438335986	1.0140517	0.32209987	-7.926009356	23.0117236

Hypothesis 9: Is there is a relationship between the students' RLO usage and their overall academic grades in Design 102.

Regression Statistics	
Multiple R	0.290892937
R Square	0.084618701
Adjusted R Square	0.041029115
Standard Error	11.81044342
Observations	23

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	270.7796468	270.7796468	1.941259575	0.178105386
Residual	21	2929.218048	139.4865737		
Total	22	3199.997694			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	57.94619871	4.778733877	12.1258476	6.00572E-11	48.00827758	67.88411984
Participation Rates-RLO's in SEM 2	5.249497184	3.767696413	1.393290915	0.178105386	-2.585856439	13.08485081

Hypothesis 9: Is there is a relationship between the students' RLO usage and their end of term exam grades in Design 102.

Regression Statistics	
Multiple R	0.439493252
R Square	0.193154319
Adjusted R Square	0.154733096
Standard Error	14.04437736
Observations	23

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	991.6038845	991.6038845	5.027281906	0.035875961
Residual	21	4142.135246	197.2445355		
Total	22	5133.73913			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	58.54918033	5.68640218	10.29634881	1.15896E-09	46.72365963	70.37470103
Participation Rates-RLO's in SEM 2	9.668032787	4.311927946	2.242160098	0.035875961	0.700887733	18.63517784

Appendix H: Comparison of CAO Entry Points

CAO Points	
2014/2015	**2015/2016**
210	240
315	205
350	275
260	420
330	370
285	230
335	460
260	355
330	370
420	200
370	230
265	220
445	195
355	420
275	240
280	315
185	285
280	315
255	210
250	205
260	210
240	280
280	190
350	375
280	405
535	405
375	250
280	240
250	345
225	265
270	305
295	235
355	395
275	315
360	265
405	400
335	380
160	400
	380
	240
	335

t-Test: Two-Sample Assuming Unequal Variances		
	2014/2015	*2015/2016*
Mean	304.8684211	301.8292683
Variance	5352.009246	6223.445122
Observations	38	41
Hypothesized Mean Dif	0	
df	77	
t Stat	0.17766029	
P(T<=t) one-tail	0.429728157	
t Critical one-tail	1.664884537	
P(T<=t) two-tail	0.859456313	
t Critical two-tail	1.991254395	
Decision	Do not reject null hypothesis	

Appendix I: Summary of CAO Student Profiles 2015/2016

Dummy Variable for previous study of CAD	0= NO 1= Yes

Participation Rates-RLO's	
High usage	3
Medium usage	2
Low usage	1
No usage	0

Respondent	CAO	Previously Studied CAD	Participation Rates-RLO's in SEM 1	CA Grade Sem 1	Exam Grade Sem 1	Overall Grade SEM 1	Participation Rates-RLO's in SEM 2	CA Grade Sem 2	Exam Grade Sem 2	Overall Grade SEM 2	Participation Rates in RLO's With No Previous Experience
Respondent A 2	240	0	1	67	41	54	0	42	34	38	1
Respondent A 4	275	0	0	60	71	65	1	66	75	71	1
Respondent A 10	355	0	0	51	62	57	0	42	35	39	0
Respondent A 11	370	0	1	49	86	68	1	52	89	71	2
Respondent B 1	200	0	0	23	31	27	1	29	53	41	1
Respondent B 2	230	0	1	44	79	62	1	49	64	57	2
Respondent B 3	220	0	1	54	30	42	2	61	51	56	3
Respondent B 4	195	0	1	42	73	58	1	39	74	57	2
Respondent B 5	420	0	1	79	83	81	2	76	82	79	3
Respondent B 9	285	0	1	91	56	74	1	85	65	75	2
Respondent C 1	210	0	0	26	27	27	2	53	70	62	2
Respondent C 3	205	0	0	76	81	78	0	81	63	72	0
Respondent C 7	280	0	1	49	86	68	1	52	76	64	2
Respondent C 8	190	0	1	59	72	65	1	51	71	61	2
Respondent C 13	250	0	0	53	50	52	1	63	64	63	1
Respondent C 14	240	0	1	50	72	61	2	68	85	76	3
Respondent D 5	305	0	1	82	90	86	1	77	86	81	2
Respondent D 6	235	0	1	42	16	29	1	55	68	62	2
Respondent D 7	395	0	1	62	71	67	2	50	81	66	3
Respondent D 10	265	0	0	66	57	62	1	74	66	70	1
Respondent D 12	380	0	0	74	84	79	0	65	86	75	0
Respondent D 15	240	0	1	78	87	82	2	32	89	61	3
Respondent D 16	335	0	1	59	50	54	2	68	71	70	3

Summary of CAO Student Grades 2015/2016

Respondent	CAO	Previously Studied CAD	Participation Rates-RLO's in SEM 1 with EXP	CA Grade Sem 1	Exam Grade Sem 1	Overall Grade SEM 1	Participation Rates-RLO's in SEM 2	CA Grade Sem 2	Exam Grade Sem 2	Overall Grade SEM 2	Participation Rates in RLO's With Previous Experience
Respondent A 3	205	1	0	39	31	35	0	21	33	27	0
Respondent A 5	420	1	1	78	97	87	1	44	88	66	2
Respondent A 6	370	1	0	87	94	90	0	90	91	91	0
Respondent A 7	230	1	0	74	89	81	0	83	88	85	0
Respondent A 9	460	1	0	86	92	89	0	75	92	84	0
Respondent B 7	240	1	0	58	79	69	0	47	81	64	0
Respondent B 8	315	1	0	83	89	86	0	89	91	90	0
Respondent B 11	315	1	0	92	68	80	1	90	88	89	1
Respondent C 5	210	1	0	39	66	52	1	40	60	50	1
Respondent C 9	375	1	1	81	93	87	1	90	91	91	2
Respondent C 11	405	1	0	50	64	57	1	47	63	55	1
Respondent C 12	405	1	0	64	93	78	0	79	85	82	0
Respondent D 4	265	1	0	59	37	48	1	61	62	61	1
Respondent D 8	345	1	1	89	70	79	2	52	74	63	3
Respondent D 9	315	1	2	86	87	86	2	24	84	54	4
Respondent D 11	400	1	0	87	89	88	0	80	79	80	0
Respondent D 13	400	1	0	91	97	94	0	94	89	91	0
Respondent D 14	380	1	1	74	68	71	1	79	77	78	2

Appendix J: Summary of CAO Student Profiles 2014/2015

Respondent	CAO	Previously Studied CAD	CA Grade Sem 1	Exam Grade Sem 1	Overall Grade SEM 1	CA Grade Sem 2	Exam Grade Sem 2	Overall Grade SEM 2
Respondent E 1	210	No	41	41	41	44	42	43
Respondent E 2	315	Yes	62	73	68	36	69	53
Respondent E 3	350	Yes	71	51	61	78	77	78
Respondent E 4	260	Yes	44	72	58	25	48	37
Respondent E 5	330	No	62	85	74	24	59	42
Respondent E 6	285	No	69	49	59	70	71	71
Respondent E 7	335	No	51	71	61	51	77	64
Respondent E 8	260	Yes	48	64	56	30	69	50
Respondent E 9	330	Yes	50	71	61	54	74	64
Respondent E 10	420	Yes	74	94	84	63	84	74
Respondent E 11	370	No	68	71	70	41	78	60
Respondent E 12	265	Yes	75	60	68	73	70	72
Respondent E 13	445	Yes	74	79	77	66	85	76
Respondent F 14	355	No	65	56	61	66	62	64
Respondent F 15	275	No	45	38	42	40	51	46
Respondent F 16	280	Yes	71	73	72	57	75	66
Respondent F 17	185	Yes	80	79	80	82	80	81
Respondent F 18	280	No	74	23	49	54	25	40
Respondent F 19	255	Yes	68	78	73	59	77	68
Respondent F 20	250	Yes	62	40	51	52	71	62
Respondent F 21	260	No	81	96	89	52	73	63
Respondent F 22	240	No	69	75	72	60	79	70
Respondent F 23	280	No	80	95	88	84	76	80
Respondent F 24	350	No	82	94	88	78	89	84
Respondent F 25	280	No	22	31	27	58	65	62
Respondent F 26	535	Yes	84	97	91	97	95	96

Summary of CAO Student Profiles 2014/2015

Respondent	CAO	Previously Studied CAD	CA Grade Sem 1	Exam Grade Sem 1	Overall Grade SEM 1	CA Grade Sem 2	Exam Grade Sem 2	Overall Grade SEM 2
Respondent G 27	375	No	57	72	65	43	34	39
Respondent G 28	280	No	62	64	63	38	50	44
Respondent G 29	250	Yes	65	81	73	68	70	69
Respondent G 30	225	No	56	55	56	65	45	55
Respondent G 31	270	No	66	22	44	38	45	42
Respondent G 32	295	No	56	54	55	81	73	77
Respondent G 33	355	Yes	55	31	43	67	70	69
Respondent G 34	275	Yes	58	33	46	55	63	59
Respondent G 35	360	Yes	61	48	55	51	48	50
Respondent G 36	405	Yes	57	91	74	62	74	68
Respondent G 37	335	Yes	37	89	63	53	82	68
Respondent G 38	160	No	56	25	41	53	40	47

Appendix K: Interviewee Selection

Selected Participants for Interviews											
	CAO	**Previously Studied CAD**	**Participation Rates-RLO's in SEM 1**	**CA Grade Sem 1**	**Exam Grade Sem 1**	**Participation Rates-RLO's in SEM 2**	**CA Grade Sem 2**	**Exam Grade Sem 2**	**Interviewees**	**Interviewed Yes/No**	**Duration (mins)**
Student B 1	200	NO	0	23	31	1	29	53	INT	Yes	25
Student B 3	220	NO	1	54	30	2	61	51	INT	Yes	36
Student C 1	210	NO	0	26	27	2	53	70	INT	Yes	35
Student C 5	210	YES	0	39	66	1	40	60	INT	Yes	28
Student C 9	375	YES	1	81	93	1	90	91	INT	No	
Student C 11	405	YES	0	50	64	1	47	63	INT	No	
Student D 6	235	NO	1	42	16	1	55	68	INT	Yes	33
Student D 7	395	NO	1	62	71	2	50	81	INT	Yes	37
Student D 8	345	YES	1	89	70	2	52	74	INT	No	
Student D 9	315	YES	2	86	87	2	24	84	INT	No	
										Average	32.33

Appendix L: Summary of Interview Transcript Analysis

Experience Section Interview Questions

	1. How did you find this blended learning approach?
Emergent Theme	Further developed their knowledge and skills outside of class time
(D7)	*"There's no one to ask for help when you are on your own when away from college. The videos answered these questions for me"*
(C1)	*"provided extra material outside class time"*
(D6)	*"didn't have to travel to college to access the videos. It was great to be able to look at the videos from home"*
(B3)	*"there can be too much material covered in class that you can't remember half the stuff. I used the videos a lot to go back over the material at home"*

	2. Do you think the use of RLO's as a blended learning tool has helped or hindered your studies? And how?
Emergent Theme	The RLO's reinforced material that students didn't understood in class
(D6)	*"They massively helped. If you are struggling in class, not understanding what's going on, it gets frustrating".*
(B3)	*"I would have struggled to pass the subject without the videos. I found it hard to get the exercises finished during the three hours of class. The videos allowed me to catch up".*
(C1)	"*In class I always felt that I was falling behind the rest of the lads, as it moves at such a fast pace. These videos allowed me to work the exercises at my own pace and from the comfort of my own room".*
(D7)	*"the videos were a great help to me in getting used to SolidWorks and getting the exercises complete".*

	3. What worked well in using this blended learning approach?
Emergent Theme	Access to material for revision and clarifying key points
(D7)	*"I found it very useful when I didn't get something in class. I could look over the stuff from home and catch up". At the start of the course I was struggling to understand how to use SolidWorks, while those next to me were flying along".*
(C1)	*" the RLO's seemed to make things simpler and easy to understand"*
(D6)	*"It worked well because if you missed a class you could easily catch up in your own time"*

	4. What didn't work well in using this blended learning approach?
Emergent Theme	Some form of incentive may be required to encourage further usage of RLO's
(C1)	*"I wish I had used them more in the first semester, maybe I wouldn't have failed"*
(B1)	*"I didn't use the videos half enough... probably because I didn't put in any effort until near the end"*
(C5)	*"I wish I made more use of the videos as my result wasn't very good".*

Usage Section Interview Questions

	5. Did you find the content of the RLO's was at a suitable level?
Emergent Theme	The RLO's contained key points which were relevant to their studies
(D6)	" *The section with the short video clips that showed stuff like putting a thread on a part was very useful, especially when it came to doing the drawings, as I always forgot how to do it or missed that part when it was shown in class".*
(B3)	*"They were very easy to follow. I really liked how time was spent at the start explaining where to locate the origin".*
(C5)	*"I found the videos useful for revision prior to the exam to remember parts that I didn't understand fully in the class. They helped me remember the key points which I found useful"*
(D7)	*" The RLO's always pointed out key points and helped me get my exercises done"*

	6. Do you think the design of the RLO's was suitable in terms of the visual and sound effects? Why, or why not?
Emergent Theme	Some audio concerns but overall the design of the RLO's was suitable.
(C1)	*"Yeh of course, the audio was clear and I was able to minimize the window to work on SolidWorks at the same time".*
(B1)	*"Sound varied from PC to PC but I don't think that was the fault of the video. Overall I think they were fine."*
(B3)	*"Yeh they were fine, easy to follow and work through. There were a few sound issues with the first few videos but fine after that."*

	7. How did you find the reusability features of these RLO's, was the video duration suitable?
Emergent Theme	RLO's were flexible, easily accessible and of suitable duration
(D6)	*"The duration of the RLO's was ideal. Some exercises I played back four or five times as it was so easy to keep going back."*
(C1)	*"For each exercise there was three or four short videos, which was great.* *It was very easy to pause and go back again or even skip forward to where you wanted to be".*
(B3)	*"The duration was good. You could pause it and move the video to the part you want."*
(D7)	*"The way each exercise was broken down into small chapters was very useful. If would be useful to have bullet points to let you know what features are in the videos."*

	8. Do you think you will access these RLO's again throughout your study? Why, or why not?
Emergent Theme	Strong consensus that the RLO's would be accessed againg throughout their studies
(B3)	*"Yeh definitely and I'm pretty sure I will have to access them at the start of September to go back over material, 100 per cent go over them again."*
(D6)	*"Yeh before I go back in August to refresh and during if the course if they are available."*
(D7)	*"I will as when you are away from it for a while you forget the basics."*
(C5)	*"I probably will need to during the course as I tend to forget some of the basic things in SolidWorks a lot."*

Recommendations Section Interview Questions

	9. Would you recommend the use of RLO's to other students? Why?
Emergent Theme	Students would strongly recommend the use of this blended approach
(D6)	*"Yeh definitely. I'm going to be a mentor this year and I will be informing the students of how useful the RLO's are."*
(C1)	*" Yes I would recommend them and I would advise them to use them from day one and not leave it too late."*
(D7)	*"Yeh definitely would. I never use SolidWorks before so it helped me gain confidence and was handy to have that bit extra to go back on."*
(B3)	*"Definitely. If you didn't take notes in class you were lost trying to finish the exercises."*

	10. In your opinion, do you think blended learning could totally replace "face-to-face" interactions? Why, or why not
Emergent Theme	Students like the interaction with their teachers. Blended learning gives a good balance.
(D7)	*"No don't think so. Use it to back up what's learned in class. You can't beat been able to ask questions in class."*
(B3)	*"No. In class you can ask questions or questions you might not think of asking could be asked in class."*
(C1)	*"Blended is good but I wouldn't want to have it all online. Face-to-face learning allows you to ask questions in person when you get into difficulty, however, blended learning gives a great balance of both."*
(D6)	*"It would depend on the individual student as some that have done SolidWorks were flying ahead of the rest of the class. I could see it work."*

List of Abbreviations

CAD: Computer Aided Design

LO: Learning Object

HEI: Higher Education Institute

ICT: Information and Communications Technology

LORI: Learning Object Review Instrument

REC: Research Ethics Committee's

RLO: Reusable Learning Object

TAM: Technology Acceptance Model

VLE: Virtual Learning Environment