EXPLORING DIFFERENTIAL LEVELS OF FEEDBACK IN DIGITAL LEARNING OBJECTS

By

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A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Psychological Studies in Education

Department of Educational Psychology

University of Alberta

Abstract

The paper explores the effect of embedding differential levels of elaborated feedback into digital learning objects. The effect of the embedded feedback is also considered in relation to computer experience and learner characteristics. Three digital learning objects were developed for this study and were based on three Calculus topics that were common to all of the participants in their post-secondary Engineering courses. Three experiments were conducted using the three separate digital learning objects and participants within each of the digital learning object groups, were randomly assigned to one of three different treatment conditions; simple feedback, positive feedback and negative feedback. The participants used the digital learning objects as regularly scheduled activities in their classroom activities with the learning objects and subsequent post-tests delivered through the Moodle Learning Management System. Results were analysed using a two-way analysis of variance (ANOVA) and indicated that there was no significant difference between simple, positive and negative feedback directly, however, when analyzing the results in relation to computer experience, it was found that test score results for participants receiving positive and negative feedback were significantly higher for participants with high computer attitude. This study is expands on research on feedback on the use of feedback in the learning context of digital learning objects and in relation to the learner characteristic of computer attitude. As Hatziapostolou and Paraskakis (2010) have noted, feedback is an important component in all learning contexts, and as Van der Kleij, Feskens and Eggen (2015) have suggested, there has been little further experiments in feedback should also account for the learning context. Furthermore, they also suggest that additional research in feedback should include learner characteristics.

Preface

This thesis is an original work by John Doe. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name "EXPLORING THE EFFECTIVENESS OF DIFFERENTIAL LEVELS OF FEEDBACK IN DIGITAL LEARNING OBJECTS", No. Pro00045923, January 2,2015. The research project, also received research ethics approval from the Northern Alberta Institute of Technology Research Ethics Board, No. 2015-02, January 12, 2015.

This thesis is an original work by Todd Sumner. No part of this thesis has been previously published.

Acknowledgements

Doctoral supervisor: Dr. Patricia Boechler

Supervising committee members: Dr. Florence Glanfield, Dr. Mike Carbonaro

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CHAPTER ONE – INTRODUCTION

Background

There are many challenges involved in designing effective online courses with some of these challenges arising from the fact that designers must create an environment that responds to the students' needs in terms of providing effective feedback. In a face-to-face classroom setting, feedback is typically instructor driven in that the instructor controls the timing, type, frequency, and learning context of the feedback. An instructor in a face-to-face classroom can use feedback to adapt a lesson to the needs of a class or an individual. In an online learning environment, however, the timing, type and frequency of feedback can present both challenges and advantages when developing online courses. Bonnel (2008) has noted that rich and rapid feedback is essential for online courses given that students often feel abandoned by instructors without adequate feedback, and students and instructors typically do not often communicate in real time, that is, they often communicate asynchronously. Race (2001) has outlined a number of types of instructor driven feedback in both face-to-face and online classes and describes e-mail, discussion groups and online conferencing as ways for instructors to provide feedback to students in online settings. Race also outlines a number of significant challenges to instructor driven feedback in online courses in terms of timing and frequency since online instructor driven feedback needs to be delivered, initiated and mediated by the instructor across a distance and often asynchronously. There are, however, more opportunities for student driven feedback in online courses where students, rather than the instructor, control the timing, frequency, type and learning context of the feedback. Van der Kleij, Feskens and Eggen (2015) offer that in a computer environment, standardized feedback can be generated to the students' responses. This allows instruction to be continuously adapted to the learners and make the feedback timelier.

Brown, Lovett, Bajzek and Burnette (2006) outline a number of types of student driven feedback such as interactive animations, simulations, low stake online quizzes, and mini tutors. In general, they offer that student driven feedback could best be defined as feedback that is initiated by actions students take while interacting with software or web pages and where the instructor may or may not provide additional feedback. Race (2001) adds that online student driven feedback can be designed so that instructors can create detailed feedback that is geared towards the most likely mistakes or misconceptions that students have.

While feedback has consistently been shown to be invaluable in online courses (Bonnel, 2008; Miller, Doering, & Scharber, 2010, Van der Kleij, Feskens & Eggen, 2015), there is still a lack of good empirical studies exploring the number factors that influence the effectiveness of online feedback (Miller, Doering & Scharber, 2010; Van der Kleij, Feskens & Eggen, 2015). It has been shown that online instructional designers often place feedback in the last phase of their designs, if they do at all, with feedback typically being used for online quizzes and tests (Miller, Hooper, Rose, & Montalto-Rook, 2008). Also, designers opt for instructor-based feedback such as e-mail and conferencing since it is easier and less expensive to implement since most students have access to e-mail, and Learning Management Systems (LMS) typically have conferencing utilities built into the system. Developing effective, student-driven, online feedback also faces significant obstacles such as lack of time, limited technical skills, fear of technology, insufficient access, and a lack of understanding about how to integrate technology into an educational setting (Miller, Hooper, Rose, & Montalto-Rook, 2008). Additionally, the rapidly evolving nature of computers and learning systems often makes it difficult to implement and keep online feedback up to date.

One online learning mechanism that can potentially help to overcome some of the obstacles of including student driven feedback into the design of online courses is the use of digital learning objects. While there isn't a clear definition of digital learning objects that is universally accepted (Gadanidis & Schindler, 2006; McGreal, 2004), most authors do agree upon certain characteristics that are common to digital learning objects such as interactivity, reusability, they must be self-contained, must be digital, and must be adaptable (Chitwood, May, Bunnow, & Langan, 2002; Gadanidis & Schindler, 2006; Kay, 2007; Kay & Knaack, 2008a; Muller, Buteau & Mgombelo, 2009; Nurmi & Jaakkola, 2006; Reece, 2016; Sims, 2000;Yacci, 2000). These characteristics are useful in describing the use of digital learning objects, however, they offer little in terms of how to best design digital learning objects, and do not describe how to best incorporate student driven feedback into digital learning objects to increase learning. One of the reasons for this is that even though many authors see digital learning objects as effective online learning tools, there is a lack of empirical evidence with respect to the design and effectiveness of digital learning objects to increase learning (Kay, 2007; Kay & Knaack, 2008a ; Nurmi & Jaakkola, 2006). Kay (2007) and Kay and Knaack (2008b) found few studies related to the effectiveness and design of digital learning objects with most of the studies being qualitative. Only a handful of the studies had a quantitative design, however, they noted concerns in the design of the studies that affected the reliability and validity of many of them (Kay, 2007; Kay & Knaack, 2008b). Additionally, many studies had small sample sizes which made it difficult to generalize the results to a larger population. In terms of interactivity and feedback, only one study examined different levels of interactivity, with no studies looking at the effectiveness of incorporating feedback into the design of digital learning objects (Kay, 2007; Kay & Knaack, 2008b).

As Kay and Knaack (2008b) and Kay (2014) have noted, there has been little research in regards to learner characteristics and the effectiveness of the use of digital learning objects. The learner characteristics that have been examined are gender, age, subject ability, and computer self-efficacy, however, these learner characteristics were not studied in relation to feedback. With respect to gender, studies by Kay and Knaack (2008b) and Van Zele, Vandaele, Botteldooren, and Lenaerts (2003) have shown that there is no observable difference between males and females in regards to attitude when using digital learning objects. Kay and Knaack (2008b) did note, however, that the difference in attitude and performance for computer related tasks between males and females was significant in the early '90's, but they also indicate that recent research has shown that it has significantly decreased. Lastly, in terms of the effect of computer self efficacy and performance using digital learning objects, no current research was found. Kay (2007) does note, however, that this could be supported by the substantial body of research done in the area of computer self-efficacy and computer related behaviors. One study by Lim et al (2006) did find that students who were not comfortable with computers did tend to use digital learning objects less.

Problem

Van der Kleij, Feskens and Eggen (2015) have identified that there remains a number of gaps in the literature in the use of feedback in online settings, and specifically in the areas of feedback type, learner characteristics and learner context. When looking at digital learning objects as the learning context, Nurmi and Jaakkola (2006) have noted that there continues be enthusiasm towards designing and using digital learning objects to support online learning. However, as already noted, there is a lack of empirical studies that have investigated the design of digital learning objects in relation to increasing learning with most studies focusing on the technological aspects of the design of learning objects (Watson, 2010). Kay (2007) adds that digital learning objects have the potential to revolutionize online learning, but that it will not occur until instructional use and pedagogy in relation to digital learning objects are explored and evaluated. Kay further notes that research must look at how digital learning objects can be used to create high quality instruction and that a detailed analysis of the features of digital learning objects needs to take place. One potential area of research into digital learning objects would involve embedding feedback into digital learning objects. With feedback being shown to be one of the most effective ways teachers can increase learning, designing digital learning objects with feedback that mimics a student-instructor interaction would seem logical. Embedding feedback into digital learning objects has the potential to allow designers to create online learning environments that allow student driven feedback to be incorporated directly into online learning, and in fact, designers often build feedback into their digital learning objects. Additionally, of further interest for this study would be to look at the interaction of learner characteristics and levels of feedback in digital learning objects.

Purpose

The purpose of this study is to investigate the effect on student achievement scores of student driven feedback embedded in digital learning objects designed for post-secondary calculus students. Additionally, this study will investigate the influence of the learner characteristic of computer experience in relation to student achievement of differential levels of student driven feedback embedded in digital learning objects. This study will contribute to a better understanding of the practices in the design of interactive digital learning objects and will help to guide instructional designers in how to incorporate student driven feedback into digital learning objects. Additionally, this study will contribute to the understanding of how feedback can be used in online environment to increase learning specifically within the context of digital learning objects.

Research Questions

1. Is there a difference in post-secondary students' learning based on the type of feedback they encounter while using an online digital learning object as a basis of instruction in an introductory calculus class?

   Types of feedback in this study will be feedback that addresses faulty interpretations and not a lack of understanding in the form of either positive or negative feedback as described by Black and Wiliam (1998) and Hattie and Timperley (2007).
2. Is there a difference in post-secondary students' learning based on the type of feedback they encounter using an online digital learning object in relation to learner characteristics of computer experience?

CHAPTER TWO – REVIEW OF THE LITERATURE

Introduction

Since the advent of the personal computer in the late 1970's, there has been a consistent effort to increase the use of computers in education (McRobbie, Ginns & Stein, 2000). This is supported by a report on students, computers and learning by the organization for economic cooperation and development (OECD) which shows that computer use in education has consistently increased between 2009 and 2012 (OECD, 2015). Kay (2007) and the OECD (2015), however, report that technology has had a minor impact on student learning, and notes that the problem with the use of technology in the classroom is due to a number of obstacles that have prevented the successful implementation of technology. These include a lack of time, limited technical skills, fear of technology, insufficient access, and a lack of understanding about how to integrate technology into an educational setting for both learners and teachers. This is further supported by the OECD report that argues that schools must encourage and support changes in policies, curriculum and training for integrating computers into schools (OECD, 2015). They further argue that teachers must create new resources for integrating computers into learning. One area of computer integration into education that faces these obstacles while continuing to grow at an incredible pace is online education. That is, courses delivered online using Learning Management Systems (LMS). There has been a significant amount of research into the implementation of online courses with practices developed to address a number of these obstacles (Kay, 2007; Miller, Doering & Scharber, 2010); however, one area that is often overlooked in the development of online courses is feedback that is given to students about their learning (Diane & Richards, 2004; Hattie, Biggs & Purdie, 1996). Hatziapostolou and Paraskakis (2010) and Blair, Wyburn-Powell, Goodwin, and Shields (2014) note that feedback is important in all learning contexts, online included, but Diane and Richards (2004) and Miller, Doering and Scharber (2010) point out that instructional developers usually fail to include feedback options in the design of online learning environments. They further note that online courses are typically designed with summative assessments primarily with little or no formative assessment which could allow for effective feedback.

This review will focus specifically on the research and best practices in feedback in online education and is divided into three sections. The first section examines feedback in learning focussing specifically on face-face settings and will explore a definition of feedback in the literature followed by a general overview of feedback in relation to timing of feedback, type of feedback, learning context, usefulness of feedback and the ability of feedback to motivate. The second section of the literature review will focus on feedback in online learning and looks at instructor driven feedback versus student driven feedback. A number of factors relating to student driven feedback are more fully explored with feedback type being the focus. The third section of the literature review examines feedback in relation to the specific learning context of digital learning objects. This section begins with a general overview of feedback and digital learning objects followed by a section that explores what digital learning objects are and a general review of the literature of digital learning objects. The final portion of this section on digital learning objects focuses on factors that impact learning with digital learning objects such as attitude, design and learner characteristics. This also includes a comparative section on computer assisted instruction. The literature review ends with a conclusion that includes identified gaps in online feedback with an overview of the factors that will be explored in this study to help fill in the identified gaps.

Feedback Defined

When looking at the effectiveness of feedback one must first look at the definition of feedback since how it is defined will affect how findings are interpreted. While the term feedback is used and defined differently in various disciplines, a number of authors have defined feedback focussing on various aspects of feedback with the definitions typically being categorized in terms of gaining understanding or in terms of effect on learning.

Gaining Understanding

Hattie and Timberley (2007) define feedback very broadly as a consequence of performance and conceptualized as information provided by a variety of sources (teachers, peers, books, parents, self, and experience) in response to performance. Consequently, feedback could be interpreted as any type of information that informs the student in response to his/her performance. Other authors have a narrower definition of feedback and describe it as simply as a way to gauge whether the understanding of a topic is correct (Diane & Richards, 2004; Fleming and Levine, 1978)

Effect on Learning

A number of authors define feedback in terms of its effect. Rather than providing only information to the student about formative assessments, the feedback must also lead to student learning. That is, the student must reflect on and use the information in a way that increases learning to be considered feedback (Bonnel, 2008; Sadler, 1989; Turmond & Wambach, 2004).

For the purpose of this study, the following definition of feedback by Bonnel (2008) describes feedback in terms of its effect and can readily be applied to feedback in online courses and digital learning objects.

> Feedback is defined as communication of information to the student (based on assessment of a learning task) that helps the student reflect on the information, construct self-knowledge relevant to learning and set further learning goals. Feedback, building on assessment, allows students to gauge their progress, consider alternate learning strategies, and project their own continued learning needs. For feedback to be successful, students must reflect on and interact with the communicated information, thus taking an active role in their own learning. (p. 290)

The emphasis of this definition on the effect on learning of feedback is more in line with the concept of feedback being used as formative assessment which closely aligns with online feedback in that it typically is used for formative purposes to increase the learning in an online environment. Using this definition, there is little distinction between formative assessment and feedback with respect to purpose. The main distinction between them is that formative assessment is typically seen as more formalized purposeful assessment that helps students realign their learning, while feedback can encompass formative feedback as well as any other type of communication of information to the student that the student can use to help them take an active role in their learning by enhancing learning and achievement (Nichol & MacFarlane-Dick, 2004). Consequently, this review will distinguish between formative assessment and feedback by referring to feedback as any communication of information to the student that helps the student take an active role in their own learning, while formative assessment is a more formalized assessment such as quizzes and assignments and can be thought of as a subset of feedback.

Feedback Research

Feedback has traditionally been recognized as playing an important and significant role in student learning (Black & Wiliam, 1998; Blair, A, Wyburn-Powell, Goodwin, & Shields, 2014; Diane & Richards, 2004; Ghilay & Ghilay, 2015, Hattie, 2012; Hattie & Timperley, 2007; Hatziapostolou & Paraskakis, 2010; Sadler, 1989; Yuliang, 2009). Hatziapostolou and Paraskakis (2010) note that feedback is an important component in all learning contexts, and offer that it serves a variety of purposes such as assessment of achievement, development of competencies and understanding, and elevation of motivation and confidence. Essentially, as the definition by Bonnel (2008) shows, feedback must help the student take an active role in their learning. The definition, however, gives no insight into what constitutes effective feedback or what feedback strategies should be used. As Van der Kleij, Feskens, and Eggen (2015) add, there is “no accepted model of how feedback leads to learning” (p.476). When examining the current literature on feedback, there continues to be a significant amount of research into formative assessment, which is a form of feedback. However, Hattie and Timperley (2007) note that there has been little systematic research into feedback in classrooms, even though the importance of feedback is a recurring theme in many educational articles. Black and Wiliam (1998) in a meta-analysis of a number of quantitative studies that included feedback and various forms of formative assessment have reported large effect sizes (.4 to .7). However, these results have been criticized by a number of authors because the diversity of the studies reviewed makes compiling the results from the studies meaningless (Bennett, 2011; Van der Kleij, Feskens, & Eggen, 2015). Black and Wiliam (1998) also indicated that the number of quantitative studies with significant rigour to perform a meta-analysis is small and that the differences in the studies would make any combination of the results meaningless. Black and Wiliam (1998) do contend, however, that these quantitative studies are significantly rigorous and can stand on their own within the purposes of the studies. Another meta-analysis on formative assessment and feedback was conducted by Kingston and Nash (2011) which has also been criticized for its methodology (Van der Kleij, F. M., Feskens, R. W., & Eggen, 2015). While the research into feedback does not appear to be thoroughly explored, a reasonable understanding of what constitutes effective feedback can be developed while acknowledging that there is still a need for further research (Van der Kleij, F. M., Feskens, R. W., & Eggen, 2015).

Much of the research into formative assessment and feedback is based on work by Black and Wiliam (1998) and Sadler (1989) who state that the "learner has to (a) possess a concept of the standard (or goal, or reference level) being aimed for, (b) compare the actual level of performance with the standard, and (c) engage in appropriate action which leads to some closure of the gap" (p. 121). While Sadler (1989) was commenting primarily on formative assessment, this would also apply to all forms of feedback. The important point that Sadler makes is that for the feedback to be effective they must be aware of their standard for their learning and be able to assess their performance when compared to the standard and then change their action accordingly. Essentially, Sadler introduces the concepts of internal and external feedback with internal feedback being the internal dialogue that the student has when comparing his/her performance to a standard. Sadler notes that while many teachers give their students feedback information in regards to how they compare to the standard, there is often a difficulty when the students try to use the feedback because the student may not be able to understand the feedback or the standard may not have been fully assimilated. That is, there may be something in how the feedback was delivered or in the understanding of the standard that prevents that student from processing the feedback internally. This is reiterated by Black and Wiliam (1998), and they add that the beliefs about one's capacity to respond to feedback and the perceived risks involved in responding in different ways also contribute to how students respond to feedback. Higgins (2000) adds that students may simply be unable to understand feedback comments and correctly interpret them because they are generally delivered in academic language which the students do not understand. This is supported by Nicol and Macfarlane-Dick (2006). Blair, Wyburn-Powell, Goodwin, and Shields (2014) further add that students also are unaware that feedback is intended to help their development and learning and therefore do not use it or act on it.

Nicol and MacFarlane (2004) offer the following conceptual model in Figure 1 : A Model of Formative Assessment and Feedback that synthesizes the ideas by Sadler (2004), Black and Wiliam (1998) as well as others to help explain the feedback process. The primary focus of this is that the student is actively involved in the feedback process. The model begins with the teacher setting the task and then the students set their own goals based on their conceptions which may or may not align with the teacher's goals. The students then monitor their own progress internally by comparing their progress to their goals and they may re-interpret the task, adjust goals or adjust domain knowledge depending on the internal feedback. Additionally, external feedback on performance might agree with, disagree or augment the student's internal goals and how they interpret the task leading them to re-evaluate how they interpret the task. Nicol and MacFarlane (2004), argue that this model demonstrates that teachers should not just focus on good feedback methods, but also on helping students develop strong and effective skills of self assessment. This is also supported by York (2003) and Sadler (2004). In fact, Sadler

(2004) contends that if students are to be able to compare their performance with a standard and then take action, they must already possess some of the same evaluation skills as their teacher.

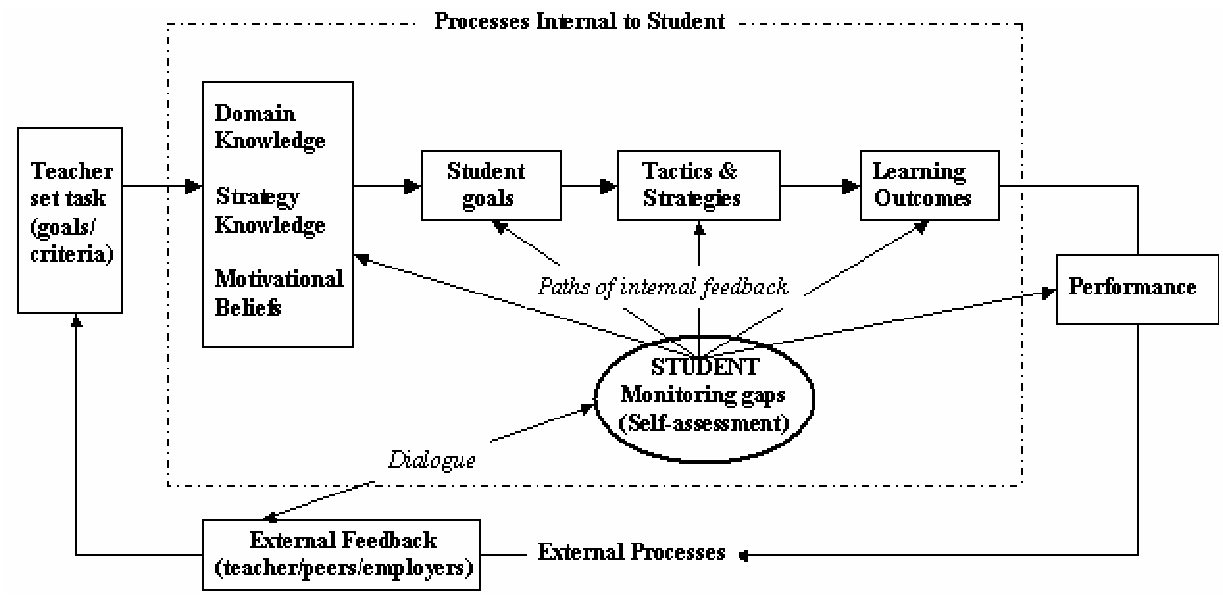


Figure 1 : A Model of Formative Assessment and Feedback (Nicol & MacFarlane, 2004). p. 2

While a conceptual model of the feedback process is important in understanding how students use feedback to increase learning, it is important to examine how feedback can best be used in a classroom or in an online setting to increase learning. Feedback research was found that looked at a number of factors that could impact the effectiveness of feedback such as timing of feedback, type of feedback, learning context, and usefulness of the feedback. Each of these is explored below.

Timing of Feedback

While there are a number of factors that have been investigated in regards to the effects of feedback on learning, timing of the feedback has consistently been shown to be important if feedback is to be effective (Brown, Lovett, Bajzek, & Burnette, 2006; Carless, 2006; Hattie &

Timperley, 2007; Hatziapostolou & Paraskakis, 2010; Miller, Doering, & Scharber, 2010). Hatziapostolou and Paraskakis (2010) argue that it is because timely feedback allows students to be able to recall how they assessed tasks and allows them to apply it to future learning and assessments. In regards to when feedback should occur, most research has shown that feedback is more effective if it occurs immediately after the students' responses (Brown et al., 2006; Hattie, & Timperley, 2007; Kulik & Kulik, 1998). However, a number of studies have shown that although immediate feedback is generally effective, it is not always necessarily so (Douglas, Salter, Iglesias, Dowlman and Eri (2016). They have found that timing of feedback is also dependent on the type of learning. They note that if the learning is for task acquisition then immediate feedback is very effective, but if feedback is for learning that represents fluency building then some delay of the feedback is beneficial (Hatziapostolou & Paraskakis, 2010; Kulik and Kulik, 1998). Corbett and Anderson (2001) also add that immediate feedback is also effective for procedure skills such as mathematics and programming. This is also supported by a meta-analysis of feedback literature in computer based instruction by Azevedo and Bernard (1995) who contend that the timing of feedback should be aligned with the outcome. Specifically, if students are learning a new task that is difficult such as mathematics, procedural or conceptual tasks, then immediate feedback is more appropriate. For simple tasks, delayed feedback is suggested as immediate feedback could be seen as an intrusion or annoyance when learning simple tasks.

Type of Feedback

Type of feedback has consistently also been shown to influence the effectiveness of feedback, specifically in terms of whether the type of feedback is either positive or negative feedback (Black & Wiliam, 1998; Davis & McGowen, 2007; Hattie & Timperley, 2007). However, the effectiveness of positive or negative feedback is contingent upon a number of factors, but first, it is important to distinguish feedback from reinforcement and punishment. Hattie and Timperley (2007) and Hattie (2012) have argued that praise, punishment, and other rewards are not effective forms of feedback and, in fact, Deci, Koestner and Ryan (1999) contend that rewards (praise) and punishments should not be thought of as feedback at all, but instead, they should be thought of as contingencies to activities. Hattie and Timperley (2007) support this position and argue that feedback should not be thought of as reinforcement since, unlike reinforcement, it can be accepted, modified, or rejected. They further add that feedback is different from reinforcement or punishment in that it contains information about the task while reinforcement does not. Hattie (2012) adds that rewards combined with praise can impede the effectiveness of feedback because it can prevent a student from hearing feedback because they focus on the reward. Given that feedback should not be thought of as either reinforcement or punishment, how then does positive or negative feedback influence learning? While most studies show that positive feedback is generally more effective that negative feedback (Black & Wiliam, 1998; Davis & McGowen, 2007; Hattie & Timperley, 2007), some authors have found there are additional factors that may determine when one is more effective than the other. Van-Dijk and Kluger (2001) argue that positive feedback is more motivating for tasks that people want to do (i.e, they are committed to a goal) while negative feedback may better support learning when people are not committed to it. They warn though, that increased learning in response to negative feedback is often short lived and often leads to avoidance behaviour. Marie (2016) did find that students reported that negative feedback was important for work that was marked because it provided information on where they had made mistakes or gone wrong.

However, positive feedback is likely to increase persistence and increase interest in an activity (as cited in Hattie & Timperley, 2007). Black and Wiliam supports this and adds that not all feedback in a classroom is beneficial, especially in discussions and questions as teachers often are looking for specific responses to questions and may inhibit learning by impeding thoughtful unanticipated responses. Another interesting finding regarding the effectiveness of positive feedback is that studies have shown that positive feedback supports processes that are critical to developing intelligence such as stimulating self-regulation (Davis & McGowen, 2007).

Shute (2008) expanded the discussion of types of feedback by identifying two broad types of feedback as verification and elaboration. Verification feedback is simply confirming to the student that an answer is correct or incorrect. This can include various forms of verification feedback in what Van der Kleij, Feskens and Eggen (2015) summarize as knowledge of results (KR) and knowledge of correct response (KCR). Knowledge of results (KR) is a form of verification feedback back that simply confirms to the student whether an answer is correct or incorrect, but can also include feedback such as error flagging which points out to the student where the error was made. Primary to knowledge of results feedback is that no additional information is provided to the student. Knowledge of correct response (KCR) feedback is similar to knowledge of response feedback, however, its purpose is to provide the correct answer, but it too does not provide additional information to the student. Elaboration, however, is more varied, but primarily has the purpose of providing more information to the student by explaining the response is correct or not. Elaborative feedback can include feedback such as hints, extra information or explanation of the correct answer, explanation of misconceptions to name a few. In relation to positive and negative feedback, Shute (2008) describes response contingent feedback as a type of elaborative feedback “that focuses on the learner’s specific response. It may describe why the incorrect answer is wrong and why the correct answer is correct" (p.160). Shute (2008) also identifies additional need for research in this area and specifically with feedback that elaborates typical errors, or negative feedback.

Learning Context

In learning contexts, Diane and Richards (2004) contend that most faculty and instructional staff often do not consider feedback during the curriculum design process and, that during instruction, feedback is typically associated primarily with marking and assessment. This results in feedback being used primarily as summative feedback and it therefore is delivered too late in the learning process to help students improve their understanding. Hattie, Biggs and Purdie (1996), however, in a meta-analysis of studies involving learning skills interventions, note that feedback is most effective when it is designed into the learning process specifically if it provides learning cues or reinforcement, and primarily if it is related to the learning goals. Furthermore, Hattie and Timperley (2007) add that the learning context is also important when embedding feedback into the learning process. They note that feedback should address faulty interpretations and not a lack of understanding; in fact, they suggest that feedback that addresses a lack of understanding can be threatening to a student.

Usefulness of Feedback

Another significant factor of feedback is that it must be useful to the students if they are to use it to improve learning. While this may seem self evident, Black and Wiliam (2010) note that most feedback and assessment emphasizes marks and grading, and not on giving useful advice to help in the learning process. They suggest that when marking and grading is emphasized, it tends to foster competition which may have a negative impact on low achieving students potentially leading them to believe that they lack ability. Additionally, Carless (2006) notes that students often report that they are not satisfied with the feedback they receive and that the feedback typically lacks information to help them improve, or is difficult to interpret. Black and Wiliam (2010) instead recommend that feedback should focus on the usefulness of the feedback to an individual student by focusing on the individual students work and how he/she can improve rather than focussing on competition. This is also supported by Hatziapostolou and Paraskakis (2006) who add that feedback must fit to each student's achievement and tailored to their individual strengths and weaknesses, but caution that overly detailed and too much feedback can result in the feedback being too confusing and overwhelming to be useful. Hepplestone and Chikwa (2014) also found that students' use of feedback was increased when connections were made between feedback they have previously received and the learning they were involved in currently. They also found that students used and valued the feedback they received, internalizing it for the future. This is supported by Marie (2016) who found that students found feedback the most valuable when it was useful for future learning which is supported by Small and Atree (2015) who note that students found the most useful feedback to be feedback that closed the gap between what they submitted and what was expected of them. Lastly, Brown et al. (2006) add that for feedback to be useful, it should also lead the students to revisit the activity.

Motivational

A number of authors have suggested that feedback also serves as a significant motivating factor in the learning process (Carless, 2006; Hattie & Timperley, 2007; Hatziapostolou &

Paraskakis, 2010; Marie, 2016). While the other factors mentioned here are factors that influence the effectiveness of feedback, motivation instead should be seen as both a factor that influences its effectiveness and as a by-product of effective feedback. That is, motivation can be seen as a quality of effective feedback given that feedback is motivational and will encourage student engagement and persistence in a task (Hattie & Timperley, 2007). Hatziapostolou and Paraskakis (2010) add that feedback can have either a positive or a negative effect on student emotion and self-esteem. They recommend that feedback should be both empowering and constructive to better increase student motivation on a task. As already noted, Van-Dijk and Kluger (2001) have shown that the motivational aspect of positive feedback is significant for tasks that students want to do and less motivational for tasks that students have to do. Thus the motivational aspect of feedback is tied to how committed we are to a goal. If we are highly committed to a goal then positive feedback is shown to be much more motivational, and will also increase the likelihood we will persist in the activity and also that likelihood that there will be an increase in measures of self efficacy. Carless (2006) offers an explanation for the influence of positive feedback on student motivation. Carless notes that assessment is an emotional process in which students make an emotional investment on an assignment or exam and expect some return on the investment. If feedback is negative, it can be threatening to a student's self-perception and self efficacy. This is further supported by Hatziapostolou and Paraskakis (2010) who have noted that a significant number of students do not collect feedback for a number of reasons, one of which is avoidance in case of bad performance which may affect their self perception. This is in contrast to what Marie (2016) found. Marie notes that students reported that feedback that showed them where they were wrong were more motivated and less worried about the course because they knew what was required.

Feedback in Online Courses

While feedback has been shown to be an effective method of improving student learning, the introduction of the computer and internet into educational settings has allowed for significant opportunities for increases in the frequency, timing and types of feedback. Online course designers have many options for feedback available to them with many more being made available all the time. When looking at feedback in a face-to-face classroom setting, feedback was typically instructor driven in that the instructor determined the timing, type of feedback, frequency of feedback and the learning context of the feedback. As shown, to use feedback effectively, the instructor had to be mindful of these factors, and the instructor had to be mindful of the needs of the students. Little research seems to have been executed around student driven feedback in face-to-face classrooms (Miller, Doering & Scharber, 2010). In online learning environments, instructor driven feedback is also widely used, however, there is much more opportunity for student driven feedback where the student determines the timing, frequency, type, and learning context especially when the feedback is delivered through Learning Management Systems that may also include adaptive feedback (Brown, Lovett, Bajzekand & Burnette, 2006).

Instructor Driven Feedback in Online Courses.

Instructor driven feedback in online courses typically is very similar to feedback in a face-to-face instructional setting. In both online and face-to-face instructional settings, feedback is created by the instructor and dependent upon the instructor for timing and frequency, and both share many of the same advantages and disadvantages. The difference between the two settings is that online feedback is offered at a distance and can be delivered either synchronously or asynchronously. What this means for the student is that they are separated from their classmates and instructor by space and, for asynchronous classes, by time. This separation offers unique challenges and advantages for the students and instructors in online classes. These challenges and advantages can apply to factors that are similar to those of a face-to-face classroom which include timing and frequency of feedback, type of feedback, and message type. In addition to these challenges and advantages, Small and Attree (2015) note that online students have a limited relationship to the instructor and have a higher belief in the expertise of the instructor which may positively impact how they receive feedback.

Timing and frequency of instructor driven feedback in online courses can present both challenges and advantages (Leibold & Schwartz, 2015). Leibold and Schwartz (2015) have noted that effective online, instructor driven feedback, is important for student learning and an essential skill for instructors to develop. Additionally, Bonnel (2008) and Leibold and Schwartz (2015) have noted that rich, timely and rapid feedback is considered essential for online courses and Bonnel (2008) states that those students who do not receive frequent feedback often feel abandoned in courses which may lead to attrition. Bonnel further notes, however, that faculty often express concern over the amount of time needed to provide feedback to students in courses while also questioning the effectiveness of the feedback. Jarvenpaaa and Leidner (1998) note that students report that timely and frequent feedback from instructors is essential to help build trust with the student and to give the student the feeling that someone is there. This is also supported by Billings (2000) who notes that timely and frequent feedback helps overcome feelings of isolation. Thurmond (2003) adds that it helps ensure students they are meeting the course expectations and maintaining the correct pace and schedule. One of the biggest difficulties in providing timely feedback in asynchronous courses is that students and instructors do not communicate in real time. However, feedback in asynchronous courses such as e-mail and discussion forums can allow for more frequent and personalized feedback from the instructor, and can allow for timely and frequent communication between the student and other students (Bonnel, 2008). Cobb, Billings, Mays, and Canty-Mitchell (2001) suggest that feedback such as e-mail and discussion forums in an online course may be beneficial because more frequent and timely feedback allows students who are typically reluctant to ask questions or to seek guidance to do so. Additionally, the timing of online feedback may allow students more time to reflect on responses. However, they also suggest that it is important for instructors to let students know when and how often to expect feedback from instructors.

Another important consideration in instructor driven feedback in online courses is how the effectiveness of the feedback is affected by the type of feedback. When discussing feedback in general, the question of the type of feedback centers on whether feedback is positive or negative in nature. While this consideration is equally important in online education, the discussion and implications are essentially the same as for a face-to-face classroom. When looking at type of feedback in online education, many authors also focus on how the delivery method might affect learning since the feedback is delivered at a distance. Hatziapostolou and Paraskakis (2010) note there are numerous electronic and traditional ways for providing feedback to students in an online environment. Race (2001) outlines a complete list of the types of feedback in online and face-to-face instruction and lists advantages and disadvantages for all. For online classes, Race outlines the two most common types of instructor driven electronic feedback. These include e-mailed comments on students work in which the instructor provided individual feedback on student’s work that was delivered to them by e-mail or submitted electronically in a Learning Management System (LMS) or computer conference. The advantages Race lists for e-mailed feedback can be summarized as: a) it is convenient for both the instructor and the student, it is private, b) students can refer back to the feedback again and again, c) instructors can keep track of the feedback, d) students are free and more likely to reply to the feedback, e) feedback can be tailored to the individual, and f) the instructor can take the time to edit feedback before sending it. Disadvantages that Race lists can be summarized as: a) the students may not have access to e-mail, b) they may not take electronic feedback as seriously as face to face feedback, and c) there may be a delay between when the instructor sends the feedback and when students read it. Another concern may also be that the interactive nature of a face to face conversation is lost in an e-mail which means that the tone and quality of the message may be lost (Bonnel, 2008). Bonnel suggests that there also needs to be thoughtful consideration of the content of the message when sending any text-based feedback to students. This idea is supported by Diekelmann and Mendias (2005) who argue that teachers need to reflect on the meaning and significance of the electronic feedback that they deliver to their students. Muirhead (2001) adds that the literature on social interaction in online education would suggest that giving consideration to affective approaches such as using a student's name, building community and providing encouragement would help students be more receptive of text-based electronic feedback.

Race (2001) also lists computer conferencing as another common type of instructor driven electronic feedback and outlines a number of advantages and disadvantages in using it. Computer conferencing can either be a synchronous method of interacting with students in a real time environment that more closely approximates instructor/student interaction in a face-to-face classroom or it might be an online discussion board that is not in real time where students post and reply to feedback from the instructor and from each other. Race suggests that many of the advantages of this type of feedback are the same as for e-mail and suggests that e-mail should still be used in conjunction with conferences when individualized or private feedback is necessary, however, individual feedback can also be accomplished in conferencing as well. In terms of the advantages unique to conferencing, Race offers that the instructor can provide more general feedback to a large number of students at once, or individually so everyone can see each others feedback, if appropriate. Students can then learn from this feedback and choose to reply to each other, the class or to the instructor or choose to continue discussions through e-mail. Disadvantages are that students may be less inclined to search through a large discussion board for responses that apply to them. If the conference is done synchronously, then it may be difficult to find times that all of the students are available especially if they are in geographically diverse locations. Also, students may be less inclined to reply to feedback in an online conference, however, e-mail is also an option for these students or a private discussion if the conferencing system supports it.

Blignaut and Trollip (2003) have a broader definition of feedback which goes beyond Bonnel's (2008) definition of feedback to include all communication to students in an online course and not just information provided to the student based on assessment of a learning task. They suggest that feedback in online courses be categorized into six distinct message types. While these are not necessarily factors in effective feedback of a learning task, it is essential for online instructors to be mindful of the response types when providing feedback to help the instructors better interact with the students. Blignaut and Trollip suggest that these types all serve different purposes and that the integration of all six types is important in a successful online course. The six types are grouped as either messages without academic content or messages with academic content and are as follows:

1) Messages without academic content.
    a) Administrative: Feedback that provided general administrative content, such as dates, profiles, formats, functionality of software and other organizational aspects..
    b) Affective: Messages that acknowledge learner participation and offer affective support.
    c) Other type: These include forums and message boards that offer open discussion.
2) Messages with Academic Content
    a) Corrective: These are messages that correct a users content or response to a posting
    b) Informative: These postings that the instructor users to provide information to the student on course content and provide individual feedback.
    c) Socratic: Posting that ask the student reflective questions (p. 154)

Student Driven Feedback in Online Courses.

Instructor driven feedback in online courses is typically delivered, initiated and/or mediated by the instructor and can be characterized as feedback that typically involves a dialogue between a student and an instructor or between students mediated by an instructor. Student driven feedback, however, can be classified as feedback generated by a website or computer software such as Learning Management Systems (LMS) or Computer Assisted Instruction (CAI) and can include pre-programmed computer feedback or adaptive feedback as well as computer based formative assignments and quizzes. Hepplestone and Chikwa (2014) add that technology can support feedback in student – driven feedback scenarios because it provides quick feedback, increases access to feedback and gives easy storage of feedback. Brown, Lovett, Bajzek and Burnette (2006) list a number of types of student driven feedback such as interactive animations, simulations, low stake quizzes, and mini-tutors. While the options for student driven feedback are significant, in each case they can be characterized as feedback that is initiated by actions students take while interacting with software or web pages and the instructor may or may not provide additional feedback.

Race (2001) offers a list of advantages and disadvantages to using student driven feedback, but the definition for computer based feedback Race offers is fairly narrow and applies to pre-prepared feedback responses to structured self assessment questions in computer based learning. The advantages Race suggests are:

- Students can work through computer-based learning materials at their own pace, and within limits at their own choice of time and place.
- Feedback to pre-designed tasks can be received almost instantly by students, at the point of entering their decision or choice into the system.
- Computer-based feedback legitimizes learning by trial and error, and allows students to learn from mistakes in the comfort of privacy.
- Instructors can prepare detailed feedback in anticipation of the most likely mistakes or misconceptions which they know will be common amongst their students.
- Students can view the feedback as often as they need it as they work through the package. (p. 11)

It should be further noted that each of these advantages is student driven or focused and the instructor does not need to be involved in the feedback process, however, this does not preclude the instructor from offering additional feedback. This is important for the reasons outlined earlier in terms of helping the students feel that someone is "out there" and is available to offer extra support. Race also offers the following disadvantages to using computer based feedback which can also apply to any student driven feedback:

- The instructor cannot easily tell to what extent individual students are benefiting from the feedback he/she has designed.
- Students who don't understand the feedback responses the instructor designed may not be able to question the instructor further at the time, in the ways they could have used with emailed or computer-conference-based feedback.
- The 'now you see it, now it's gone' syndrome can affect students' retention of the instructor's feedback messages, as students move quickly from one screen of information to another in the package. (p. 11)

To overcome these disadvantages of student driven feedback in online courses, it is necessary for the instructor to also be involved in the monitoring of the students progress and to also offer instructor driven feedback.

Research into the effectiveness of student driven online feedback has not been fully explored in the literature (Miller, Doering & Scharber, 2010; Van der Kleij, Feskens & Eggen, 2015) which may be due to the fact that designing student driven feedback requires significantly more time, cost, and expertise to develop. Regardless, there has been some research in a number of areas that are unique to student driven online feedback which include preferred form of feedback, frequency of feedback, adaptive feedback, and feedback type. Additionally there are a number of authors who have suggested best practices for incorporating feedback (student driven and instructor driven) into online course design (Azevedo & Bernard, 1995; Van der Kleij, Feskens & Eggen, 2015).

Self-Regulated Learning and Feedback

In relation to self-regulated learning in an online setting, Wang (2011) states that "the main advantage of e-Learning is that it overcomes the limits of time and space and provides learners opportunities to perform self-directed learning" (p. 1802). This means that online learning allows an opportunity for student driven feedback to support self-directed learning that is more difficult to achieve in a face to face environment. This is further supported by Johnson and Davies (2014) who state that online learning has "the capacity to promote the cyclical phases of self-regulated learning including task comprehension and then planning, strategizing and evaluating movement toward completion of the required task" (p. 5). While there is extensive research in self-regulated learning, Nicol and Mcfarlane (2006) looked specifically at the role that formative assessment and feedback play in self regulated learning. They argue that the purpose of formative assessment and feedback should be to allow students to become self-regulated learners. That is, “students can regulate aspects of their thinking, motivation and behaviour during learning” (p. 200). This is in contrast to what has traditionally been seen as the purpose of formative assessment and feedback where it has usually been seen as instructor driven where the instructor controls the feedback and consequently not self regulated learning (Nicol and McFarlane, 2006). This is also problematic because it has been shown that when instructors provide the feedback to the students, it is often complex and difficult for the student to interpret (Hatziapostolou & Paraskakis, 2006; Nicol & McFarlane, 2006). Another issue that Nicol and McFarlane note about instructor driven feedback is that feedback from instructors can regulate the beliefs the students feel about themselves, motivation and how they learn. They argue that self regulated feedback through a student driven or internal feedback process helps to overcome these shortcomings by allowing students to have an active role in the feedback. Furthermore, there is evidence that “learners who are more self-regulated are more effective learners; they are more persistent, resourceful, confident and higher achievers (Nicol & McFarlane, 2006). Pereira, Flores, Simão, and Barros (2016) and Zimmerman (2000) note that external feedback can also be beneficial in self-regulated learning because it provides feedback about the performance of the student which can help support students’ internal feedback by providing them a mechanism to reflect on the learning and competencies. The study by Pereira, Flores, Simão, and Barros (2016) further found that feedback provided during the learning process is perceived by students to be more effective and more relevant than feedback found in the assessment tests. They argue that feedback that is given during the learning process better enables self-regulation of the learning by the students compared to feedback during assessments.

Preferred form of feedback

Bower (2005) investigated whether allowing students to choose their preferred form of feedback has a significant effect on learning. Bower allowed students to work through an online module and then gave them access to an online practice facility with the feedback being one of two forms, competitive or individualistic. Students were assigned to groups with one third receiving their preferred method (either competitive or individualistic), one third receiving their non-preferred method and one third receiving simple feedback. Bower found that there was a significant improvement in test scores for students who received their preferred method of feedback, while students receiving their non-preferred method actually had a negative impact on their performance. While this study only examined preferred method in respect to one type of student driven online feedback (low stake quizzes), it would be interesting to examine preferred method for other types of student driven feedback such as simulations, interactive animations and digital learning objects. It would also be interesting to examine the effect of preferred type in which numerous types of student driven feedback was available to the student.

Frequency of feedback

Increased frequency of feedback has been shown to be an important factor in both face-to-face and instructor driven feedback in online courses. In respect to student driven feedback, a number of authors have shown that a high frequency of feedback also leads to a significant increase in performance (Butler, Pyzdrowski, Goodykoontz, & Walker, 2008; Cassady, Budenz, Anders, Pavlechko, and Mock, 2001; Klecker, 2007; Sonak, Suen, Zappe, & Hunter, 2002). Bower (2005) suggests that online student driven feedback, though time consuming to implement, can help lead to student mastery which might account for increases in performance.

Adaptive or Tailored feedback

One type of student driven feedback that has consistently shown a significant positive impact on student learning is adaptive or tailored feedback (Bower, 2005; Nguyen, Hsieh & Allen, 2006). Adaptive or tailored feedback is implemented in LMS or computer assisted instruction systems as well as digital learning objects when the computer gives feedback that is directly tailored to a student's response to a question or to an interaction with software. While adaptive feedback has been shown to be very effective, it is often the most difficult to implement by instructors due to constraints in time, cost and expertise, and it is also the most sensitive to changes in technology and software.

Course design

When designing online courses, it is important to ensure that feedback is included in the structure of the course (Bonnel, 2008; Miller, Doering, & Scharber, 2010), but often instructional designers place feedback as the last phase of instructional design with feedback playing a minimal role other than traditional quizzes and tests (Miller, Hooper, Rose, Montalto-Rook, 2008). Bonnel (2008) suggests that when designing a course, keeping the course goals in mind allows for the natural integration of feedback, and once goals are defined, numerous ways to provide feedback can be implemented. Miller, Doering and Scharber (2010) also suggest that the designer should understand and consider the intricate details of when to use and when to avoid different types of feedback.

While feedback has consistently shown to be invaluable in all types of education, it is often poorly implemented in online education (Miller, Doering & Scharber, 2010; Miller, Hooper, Rose, Montalto-Rook, 2008). Instructor driven feedback is the type of feedback that is most commonly used in online education likely because it is similar to the feedback in face-to-face classrooms, and e-mail and conferencing are therefore easy for an instructor to use and understand. Another reason that instructor driven feedback is more commonly used is because it is typically very easy to implement given that most students have access to e-mail and most LMS systems have conferencing utilities built into the system that an instructor can easily set up and use (Race, 2001). In regards to student driven feedback, it is much more difficult for course designers to implement. As already suggested, to create effective student driven feedback, a significant investment in time and money, along with a lack of expertise makes implementation difficult (Miller, Doering & Scharber, 2010). Many LMS systems have built in testing facilities that offer numerous options for creating low stake quizzes, however, they too take a significant amount of time and money to implement. Other types of student driven feedback take such a large commitment to implement that individuals or even smaller institutions cannot afford to implement them as the return on the investment for a small number of students is not practical.

From my observations, one encouraging trend is that software companies and textbook companies are incorporating student driven feedback into their learning systems. Another reason that instructors do not use feedback effectively in online environments is that they often do not have the experience in, or knowledge of alternative forms of student or instructor driven feedback. Instead, they tend to incorporate feedback methods made available to them by their institution, or methods that are built into the LMS system they are using.

Feedback has shown to be important in all learning contexts, from face-to-face instruction to the online learning environment. Feedback in face-to-face education requires significantly less effort and preparation to implement, as it can be as simple as a face to face conversation with a student. With online feedback, it is typically more difficult to implement effective feedback strategies because the complexities and time to incorporate effective feedback. Development costs and lack of expertise by developers also contribute significantly to the difficulty in effectively implementing online feedback.

Feedback type

As already discussed, feedback type has consistently shown to positively impact learning in a face to face environment (Black & Wiliam, 1998; Davis & McGowen, 2007; Hattie & Timperley, 2007). Specifically, Van der Kleij, Feskens and Eggen (2015) have shown that elaborated feedback (EF) seems to be the most effective in terms of increasing learning whereas knowledge of results (KR) and knowledge of correct response (KCR) typically serve corrective functions and is “not very effective in student learning because it does not inform the learner about how to improve” (p.478). This is supported by Adams and Strickland (2012) who note that knowledge of results (KR) and knowledge of correct response (KCR) feedback is not any more effective that no feedback (NR). When looking specifically at feedback in an online environment, Van der Kleij, Feskens and Eggen (2015) conducted a meta-analysis of the effects of feedback in computer based learning Van der Kleij, Feskens and Eggen (2015) and have shown that elaborated feedback is generally more effective in an online environment than simple feedback. This was especially true when looking at higher order learning outcomes. However, they have indicated that previous studies and meta-analyses in the area of feedback in online courses, and specifically feedback type, “do not shed sufficient light on the complex interplay of feedback type, feedback timing, and the level of learning outcomes and do not give usable insight into the magnitude of the effects" (p.481). Van der Kleij, Feskens and Eggen (2015) concluded that more research is needed in the area of elaborated feedback in an online learning environment. They suggest future studies looking at feedback type, and specifically elaborated feedback, and should have larger sample sizes and take into account feedback characteristics, the task, the context in which the learning takes place, and the characteristics of the learner. They also indicate that the research in elaborated feedback in online settings take place in an educational setting to "help inform practice as more and more computer-based learning environments that include feedback are being developed" (p.505).

Feedback and Digital Learning Objects

As already noted, instructor and online course developers typically implement instructor driven feedback such as e-mail and online conferencing instead of student driven feedback since student driven feedback takes such a large commitment to implement. These obstacles of time, limited technical skill, fear of technology are easily overcome using instructor driven feedback strategies as most LMS systems have many conferencing systems built in and e-mail is ubiquitous. However, these obstacles are significant with student driven feedback. Most LMS systems do have a student driven feedback mechanism which are sophisticated testing functions which do incorporate some of the important aspects of effective feedback. These testing functions allow the designer to incorporate feedback that gives comments based on a student's response to a question which allows for immediate feedback to the students. However, this type of feedback still occurs after the student has completed online learning materials. It doesn't allow for feedback while the student is engaged in the learning material such as in computer assisted instruction. As already discussed, simple feedback that emphasizes marks and grading, instead of elaborated feedback is not as effective (Black & Wiliam, 2010; Hattie & Timperley, 2007; Van der Kleij, Feskens & Eggen, 2015). Additionally, as Hattie, Biggs and Purdie (1996) have noted, feedback is most effective when it is designed as part of the learning process.

One type of online learning mechanism that helps to overcome some of the obstacles of feedback in online learning environments are digital learning objects. Digital learning objects are an effective method of implementing technology in an educational setting (Kay, 2014). While digital learning objects are still time consuming and expensive to produce, once created, they can easily be incorporated into any Learning Management System (Kay, 2007; Kay & Knaack, 2008a; Kay, 2014; Nurmi & Jaakkola, 2006; Reece, 2016). Additionally, digital learning objects can be programmed to incorporate student driven feedback during or after the learning process, can control timing of the feedback, and can be used to incorporate different types of feedback such as simple or elaborated feedback (Kay, 2014).

Digital Learning Objects Defined

When looking at digital learning objects and how to use feedback in learning objects, one must first look at the definition of a digital learning object since how they are defined will affect how we interpret any findings. This is because there is far from agreement on what a learning object is (Gadanidis & Schindler, 2006; McGreal, 2004) with many authors not distinguishing between learning objects and digital learning objects. Many authors have attempted to define what a learning object is and there are a broad range of definitions. Kopp and Crichton (2007) note that definitions of learning objects range from people as resources to digital content such as pictures. Also, learning objects are seen to some as primarily digital content while others include non-digital content in their definitions. Kopp and Chrichton (2007) have noted that many definitions of learning objects also include instructional context. These definitions offer a very simple view of learning objects as solitary media which include graphics, animation, and video clips. It is assumed that teachers will provide the instructional context for the learning objects by incorporating them in a lesson that is useful, meaningful and effective. Still other definitions consider learning objects primarily as web-based learning tools (Gadanidis & Schindler, 2006; Kay, 2007; Kay and Knaack, 2008a).

There are, however, a number of characteristics that most definitions have in common. These include interactivity (Gadanidis & Schindler, 2006; Hui, 2012; Kay, 2007; Kay 2014; Kay & Knaack, 2008a; Muller, Buteau & Mgombelo, 2009; Reece, 2016, Sims, 2000; Yacci, 2000), reusability (Chitwood, May, Bunnow, & Langan, 2002; Nurmi & Jaakkola, 2006; Kay, 2007; Kay 2014), digital (Chitwood et al., 2002; Gadanidis & Schindler, 2006; Nurmi & Jaakkola, 2006; Kay, 2007; Kay and Knaack, 2008a; Muller et al., 2009), self-contained (Chitwood et al., 2002; Gadanidis & Schindler, 2006; Kay, 2007), and adaptability (Chitwood et al., 2002; Kay, 2007). The characteristics of interactivity, reusability, digital, self-contained, and adaptability offer a fairly concise definition of learning objects that would best be described as digital learning objects. However, these characteristics primarily define how digital learning objects are to be used, but not how they are designed to impact learning. Someone who wishes to design an effective digital learning object would get little help from such a definition as they do not describe the elements that make a digital learning object effective at increasing learning. Also, many investigations into the effectiveness of digital learning objects typically define learning objects that they use in their investigations in terms of these characteristics, but make little effort to describe them beyond these characteristics. This makes interpretation of the results very difficult as there is significant variability in the design of the digital learning objects used in the investigations.

Previous Research on Digital Learning Objects

Digital learning objects are seen by many authors as an effective learning tool with possibilities to significantly change online learning by overcoming the obstacles to online learning, however, there is a lack of empirical evidence with respect to how to effectively design digital learning objects (Kay, 2007; Kay, 2014; Kay & Knaack, 2008a; Nurmi & Jaakkola, 2006). Kay (2007) in an extensive review of the literature found 58 articles relating to digital learning objects. Of these, 50 of the papers were based on informal qualitative methods and although they examined a number of topics in digital learning objects such as design, they did not offer any empirical evidence to support their claims. The topics included design (n = 24), metadata (n = 17), learning (n = 17), reusability (n = 12), development (n = 11), assessment (n = 11), definition (n = 9), repositories and searching (n = 9), use (n = 7) and standards (n = 5). Kay and Knaack (2008b) examined 18 articles and found that although the articles addressed topics such as faculty attitudes (n =5), student attitudes (n = 11) and student performance (n = 7) the majority of the studies were also based on informal qualitative methods. Another study by Kay and Knaack (2008c) examined 22 articles and found that the majority of studies had targeted higher education (n =18) with four studies targeting secondary schools. Kay and Knaack (2008a) identified the following challenges. First, only four studies examined how teachers react to and use digital learning objects. Second, the majority of the studies only relied on one digital learning object, which made it difficult to generalize the results to other digital learning objects. Third, sample sizes in the studies were typically very small and poorly defined which also makes generalizing the results to a larger population difficult. Fourth, the majority of the studies examined only student attitude, teacher attitude or student performance. Only four of the studies examined more than one of these variables and none examined all three. Fifth, while the majority of the studies reported on the effectiveness of using digital learning objects, they mostly had poorly designed assessment tools with little reliability or validity. Only two of the studies provided estimates of reliability while only one provided data validity. The study by Lim et al. (2006) was the only study found that investigated different levels of interactivity. This was true even given that interactivity is consistently identified as one of the primary characteristics of digital learning objects.

Despite the clear lack of good empirical studies that have investigated the effectiveness and usefulness of digital learning objects, Nurmi and Jaakkola (2006) have noted that there continues to be enthusiasm towards digital learning objects and many believe that digital learning objects have the potential to transform online education. Kay (2007) notes that this digital learning object revolution will not take place until instructional use and pedagogy are explored and evaluated. Furthermore, research must look at how digital learning objects can be used to create high quality instruction and that a detailed analysis of the features of digital learning objects needs to take place.

Learning and digital learning objects

Digital learning objects offer many benefits to teachers and provide solutions to the many problems that teachers face with respect to implementing technology into their curriculum. Kay and Knaack (2008c) have identified the following benefits. First, digital learning objects are easy to use and require little time to learn how to use. Even teachers with low computer skills do not need to spend considerable time to learn how to use them. Second, good digital learning objects have well defined objectives and are focused on very specific topics. This allows teachers to easily integrate them into lesson plans or online instruction. Third, digital learning objects are easily accessible. Over 90% of all public schools in Europe and North America have internet access with the majority now having high speed internet. Finally, digital learning objects are reusable which allows the development of a single learning object to be available to a wide audience and be applied in a variety of instructional settings.

The question about what factors contribute to the effective design to increase learning remains. It must be reiterated at this point that research into the effective use and design of digital learning objects has mostly been qualitative and few studies have addressed the factors that contribute to learning from digital learning objects. Nevertheless, the studies do give insight into some of the various factors and at the very least help to identify areas where further empirical research is needed. The factors that studies have most consistently investigated are teacher and student attitude, design, and learner characteristics such as computer self efficacy, academic ability, age and gender. No studies on digital learning objects have been identified that specifically address the effect of feedback. However, previous studies on computer assisted instruction (CAI) have looked at the effect of feedback and can provide some insight into the effective use of feedback in digital learning objects. Computer assisted instruction research along with research on feedback in online learning offer a good comparison to digital learning objects and can further help to identify areas for further research.

Teacher attitude

Although teacher attitude is not directly a factor in the effectiveness of digital learning objects, teacher attitude about digital learning objects indirectly gives insight into their effectiveness. This is primarily because if teachers do not see digital learning objects as effective and easy to use, they will be less inclined to integrate them into their lessons. This is highlighted by Collis and Stijker (2003) who note three obstacles with respect to teachers who have no experience with digital learning objects and their attitudes toward digital learning objects. First, teachers did not have sufficient awareness and understanding of digital learning objects to effectively make decisions about their educational advantages. Second, teachers anticipated that it would take significant time to integrate digital learning objects into existing courses. Third, teachers anticipated that it would also take significant time to find good digital learning objects that fit well into their curriculum. Gadanidis and Schindler (2006) offer two other reasons why teachers may hesitate to incorporate investigative type digital learning objects. First, are the teacher's personal beliefs about what the students can do and how they learn. Second, teachers have concerns about classroom management issues with digital learning objects that are investigative or exploratory.

Studies that investigated attitudes of teachers who actually used digital learning objects in a classroom setting reported findings that contradict the obstacles that teachers identified above and found that teachers typically had a positive reaction to digital learning objects (Kay and Knaack, 2008a; Kay, 2014). More specifically, teachers who used digital learning objects consistently reported that they believed that students were more engaged (De Salas & Ellis, 2006), digital learning objects were beneficial to the students (Kay and Knaack, 2008a), and searching for and planning lessons with digital learning objects did not take an inordinate amount of time (Kay and Knaack, 2008c; Kay 2014). It should be noted, however, that a possible explanation for positive attitudes by teachers who were actively engaged in using digital learning objects might be that the teachers had already "bought into" the effectiveness of digital learning objects (Kay, 2014).

Student Attitude

Student attitude about the use of digital learning objects was dependent on the education level of the student with a greater percentage of students in post-secondary reporting a positive attitude towards digital learning objects as compared to secondary students. Kay and Knaack (2008a) looked at a number of studies that investigated student attitude towards learning objects with post-secondary students and found that eight studies reported positive student attitude, one study reported neutral attitude and one study reported a negative attitude. Post-secondary students typically gave positive comments about characteristics such as animations, self-assessment, attractiveness, control over learning, ease of use, feedback, scaffolding or support, interactivity, navigation, and self efficacy. Negative comments focussed on navigation problems, technology, and workload. Typically, students reported that they preferred digital learning objects that were interactive, recreation based, or collaborative.

There have been only a few studies that have looked at student attitude at the secondary level. Kay and Knaack (2008a) found that there were mixed results with student attitude at the secondary level reporting that students were only moderately positive about the quality of the digital learning objects and neutral in regards to the learning value. An interesting point is made by Kay and Knaack (2008c) with regards to student attitude at the secondary level. They note that although students were relatively neutral about digital learning objects, a significant number of students reported that they were an improvement over face-to-face teaching methods.

Further study is definitely needed in the area of student attitude given that most of the studies were qualitative and failed to control for a number of factors such as computer self efficacy, quality and type of digital learning objects, and design of the digital learning object.

Learner Characteristics

Kay and Knaack (2008b) note that although digital learning objects offer positive educational opportunities, there is very little research in regards to learner characteristics. Learner characteristics that have been examined are gender, age, subject ability, and computer self-efficacy.

In regards to gender, there were only two studies found that directly investigated the differences between males and females with respect to digital learning objects (Kay & Knaack, 2008b; Van Zele, Vandaele, Botteldooren, & Lenaerts, 2003). Both studies indicate that there was no observed difference between males and females with respect to student attitude and performance. This is reflected in the recent research into gender and attitudes about computer use. In the 1990's, males tended to have much more positive attitudes and higher ability in respect to computer use. However, current research shows that this difference has significantly lessened (Kay & Knaack, 2008b). One study did find that females tended to emphasize the quality of the help features in the digital learning objects more than males (Kay, 2007).

Kay and Knaack (2008b) found that age is a significant factor in both attitude and performance in regards to digital learning objects. They found that post-secondary students performed significantly better and had a more positive attitude than secondary students. Furthermore, grade 12 students performed better and had a more positive attitude than grade 9 or 10 students. Again no attempt was used to distinguish different types of digital learning objects in terms of interactivity. It would be beneficial to examine age differences with different types of learning objects since younger students may not perform well with exploratory digital learning objects, while older students may prefer them.

Only one study was found that measured subjects' prior knowledge as a factor in performance with digital learning objects. Nurmi and Jaakola (2006) found that there was no statistically significant difference between groups with higher and lower prior knowledge about a subject with the exception of using simulations and mixed (simulation and face-to-face labs) versus a face-to-face lab. They found that the higher knowledge students were not dependent on the learning condition, but they did find that lower prior knowledge students benefited from using the simulation.

Kay (2007) indicates that no research has been completed that examines computer self efficacy in terms of performance and digital learning objects, but anticipates that students who are more comfortable with computers would benefit more from using digital learning objects and would have a more positive attitude towards them. Kay notes that this could best be supported by the substantial amount of research done in the area of self efficacy and computer related behaviours. This research has consistently shown that positive computer attitudes are correlated with higher levels of ability. Lim et al. (2006) did report that students who were not comfortable with computers did tend to use digital learning objects less.

Design

Given the interest in digital learning objects and the large amount of research in instructional design and on multimedia elements in design, it is surprising that there is very little research on the design elements specific to digital learning objects and which design elements make learning objects most effective. Of course specific characteristics as outlined in the definition of digital learning objects are important considerations when designing digital learning objects. These include interactivity, reusability, being self-contained, and adaptability.

However, as noted previously all of the characteristics but interactivity describe the conditions for using learning objects and do not address the specific design elements that would make a digital learning object effective at increasing learning. There is a noticeable lack of research specifically in the area of the design of effective learning objects, however, design principles of multimedia learning have been investigated and are well represented in the literature. Mayer (2001) describes a number of strategies for designing multimedia learning and these strategies would certainly translate well to the design of digital learning objects.

One study by Rieber, Tzeng and Tribble (2004) showed that computer based learning with embedded explanations and graphical representations were more effective than those without. Another study by Lim et al. (2006) found that the level of interactivity in the digital learning objects was an important factor to consider in the design. Finally, Kopp and Crichton (2007) have shown that embedding digital learning objects into an online learning resource was significantly more effective than simply presenting the digital learning objects as links in the online resource.

Some authors have attempted to describe some of the effective design elements that are specific to digital learning objects. Lim et al. (2006) list a number of these effective design elements. These include chunking the content in a meaningful way, targeting the digital learning objects to specific learner types (this may impact the reusability of the learning object), and level of interactivity and control. Ally, Cleveland-Innes, Boskic and Larwill (2006) add that digital learning objects should also provide hands-on activities and examples, and that digital learning objects should be designed in a way that the learners can see the relevance of the content.

Computer Assisted Instruction and Digital Learning Objects

As noted, there has been little empirical research on how digital learning objects can be best designed to increase learning (Kay, 2007; Kay & Knaack, 2008a; Nurmi & Jaakkola, 2006) and no studies were found on the effect of integrating feedback into learning objects in terms of increasing learning. Watson (2010) contends that there has been an emphasis on the technological aspects of digital learning objects such as reusability as well as the visual appearance of the digital learning objects, but there has been a lack of research into the pedagogical basis for designing digital learning objects. Chikh (2012) adds that previous research has focussed on targeting learners as consumers of digital learning objects or targeted instructors and designers and focussed on the reusability of digital learning objects. While research on digital learning objects has not focussed on design elements that increase learning, there has been significant research in the early days of computer based learning in the area of Computer Assisted Instruction (CAI) that did focus on increasing learning. Computer Assisted Instruction is analogous to digital learning objects in many ways with the exception that digital learning objects are specifically designed to be self contained, reusable and adaptable or integrated easily into multiple learning environments. It could easily be argued that learning objects are a subset of computer assisted instruction that have developed in response to the internet and availability of learning management systems. Consequently, previous research on computer assisted instruction and specifically, research on feedback in computer assisted instruction, can inform research on feedback in digital learning objects.

Feedback research in computer assisted instruction is fairly consistent with the current research in feedback in online courses. Feedback research in computer assisted instruction has focused primarily on what Shute (2008) describes as verification or simple feedback, and Van der Kleij, Feskens & Eggen (2015) describe as knowledge of results feedback (KR). In computer assisted instruction research KR feedback is typically described as non-corrective and corrective feedback which is analogous to knowledge of results feedback (KR). Additional research also looked at elaborated feedback, but was limited to providing elaborated feedback to correct answers (positive feedback) and no studies were found that looked at feedback that provided elaborated feedback for incorrect responses (negative feedback). Furthermore, categories of elaborative feedback such as hints, error flagging, providing of explanation of correct answer and response contingent feedback were not defined in these earlier studies. That being said, the results of the studies can still be categorized in relation to the feedback types currently used to help understand the implications for feedback in digital learning objects and this study.

A number of authors exploring feedback in computer assisted instruction looked at simple and elaborated feedback. Hodes (1984) looked as simple feedback and found that there was no significant difference between corrective (KCR) and non-corrective (KR) feedback. However, Hodes did not have a control group in the study so conclusions could not be made about the overall effect of simple feedback compared to no feedback or other forms of feedback. Hodes did find that there was a significant effect for gender and reported that females receiving non-corrective feedback had significantly lower scores than males. Other researchers looked at simple non-corrective feedback (KR) and compared it to elaborated feedback and found that elaborated feedback was significantly better than no feedback and simple feedback (Collins, Carnine, & Gersten, 1987; Gilman, 1968; Lysakowski & Walberg, 1982). Additional results include an effect found for ability level and feedback as well as competitive feedback versus individual feedback. Collins, Carnine and Gersten (1987) compared simple feedback to elaborated feedback for low ability students and found a significant effect for increased learning with elaborated feedback over simple feedback. Lewis and Cooney (1986) compared a no feedback control with individual feedback and competitive feedback and found that students receiving competitive had in increase in what they describe as attributes for ability to succeed. They found no significant effect for individual feedback.

Conclusion

Current and previous studies have looked closely at feedback in both face to face and online settings with a number of meta-analyses (Azevedo & Bernard, 1995; Van der Kleij, Feskens & Eggen, 2015) showing elaborated feedback (EF) to be significantly better than knowledge of results feedback (KR) and knowledge of correct response feedback (KCR). While elaborated feedback has been shown to be more effective than simple feedback (KR) and (KCR), Van der Kleij, Feskens and Eggen (2015) identified a number of gaps in the research on online feedback that need to be further explored. They advise that more research needs to take place on the specific types of elaborated feedback. They also identify that many previous quantitative studies did not have sufficient sample sizes and that the psychometric properties of the instruments need to be reported. They specifically suggest that "future investigations should account for and describe characteristics of the feedback, the task, the learning context and the learners in order to advance the research field" (p. 505). This study seeked to extend some of these research gaps in online feedback identified by Van der Kleij, Feskens and Eggen (2015). Specifically, this study will look at two areas. First, it will look at a specific type of elaborated feedback (EF) that has not been thoroughly researched which is positive and negative feedback which Shute (2008) describes as response contingent feedback. It is the type of elaborative feedback "that describes why the incorrect answer is wrong and why the correct answer is correct" (p. 106). Furthermore, positive or negative feedback has been selected as one of the independent variables in this study since it has consistently also been shown to influence the effectiveness of feedback in face to face environments (Black & Wiliam, 1998; Davis, & McGowen, 2007). Second, this study looked at the feedback type in relation to a specific characteristic of the learner, that being, computer attitude and experience. There has been little recent research on learner characteristics in relation to the effect of feedback in digital learning objects, and the research that has been done suggests that learner characteristics do not have a significant effect on learning (Kay & Knaack (2008b) with the exception of computer self efficacy where no research has been completed Kay (2007).

The reason for selecting feedback to investigate as an effective design element in digital learning objects is because, as Hatziapostolou and Paraskakis (2010) have noted, feedback is an important component in all learning contexts. Since digital learning objects are becoming prevalent in online learning it is worth investigating whether the effect of feedback can be extended to digital learning objects as a learning context. Additionally, Van der Kleij, Feskens and Eggen (2015) have suggested that further experiments should also account for the learning context. By conducting this research specifically for digital learning objects, this study can control for learning context while giving some specific insight into the design of learning objects as well as extending the previous research on computer assisted instruction.

CHAPTER THREE – METHODOLOGY

Introduction

The purpose of this study was to investigate the effect on student achievement of different levels of student driven simple feedback and elaborated feedback embedded in digital learning objects designed for post-secondary calculus students. Specifically it looked at response contingent feedback which is an elaborated feedback type that describes why the incorrect answer is wrong (negative feedback) and why the correct answer is correct (positive feedback) (Shute, 2008). Additionally, computer experience was also considered in relation to student achievement of different levels of student driven feedback. In the design of this study, participants were selected to maximize the power of the study and to increase its validity.

Research Hypotheses

1. H_o: There is no difference in post-secondary students' learning based on the type of feedback, in online digital learning objects.
2. H_o: There is no difference in post-secondary students' learning from digital learning objects with differential levels of feedback based on the students' computer experience.

Variables

Independent Variables

1. The first independent variable (IV) is defined as the type of feedback. Type of feedback is operationalized as differential levels of feedback embedded into a digital learning object designed to instruct an introductory post-secondary calculus course. The levels of feedback were designed specifically around the learning content and were simple feedback, positive feedback and negative feedback. Three digital learning objects were created for each of the

three topics and each of the three learning objects was embedded with one of the three types of feedback. The digital learning objects embedded with simple feedback provided only simple correct or incorrect responses to the participants' answers to questions in the guided practice portion of the digital learning objects. The digital learning objects embedded with positive feedback provided elaborated feedback for only correct responses which described why the response was correct. The digital learning objects embedded with negative feedback provided elaborated feedback for only incorrect responses which described why the response was incorrect.

2. The second independent variable (IV) is defined as the computer experience of the participant. Computer experience is operationalized as the comfort level the participants have with using a computer and their attitude about computers. Computer experience was determined by a series of questions on a questionnaire given at the beginning of the study (Appendix 3), and the computer experience questions were delivered in two parts. First, computer experience was determined by a series of questions about the participant's experience with online courses, social media use, video game use, and self reported ability with using computers. The second measure was a series of questions on computer attitude using the Computer Attitude Scale developed by Nickell and Pinto (1986). The Computer Attitude Scale is a series of 20 psychometrically tested questions that returns an overall computer attitude score between 20 and 100 with 20 indicating a strong negative attitude towards computers and 100 indicating a strong positive attitude towards computers.

Dependent Variable

The dependent variables (DVs) are defined as the participant's scores on post tests consisting of multiple choice questions for each of the three digital learning objects. Essentially, three separate experiments were conducted using three separate learning objects each with their own associated post questions unique to that learning object. Consequently, the test scores for each of the post tests represents a different dependent variable and were therefore subsequently analyzed independently using ANOVA. The topics selected for each of the learning objects were common application topics taught in the first year Calculus courses that the participants were enrolled in. Each of the three topics represented a distinct topic that were determined to be independent of one another and are commonly taught in any order. That is, none of the topics requires the other two be completed as a pre-requisite. Additionally, each of the topics was based on a unique cognitive function as described by Bloom, Engelhart, Furst, Hill, and Krathwohl (1956) which made them independent from one another. The first digital learning object was on related rates in calculus and represented application as the cognitive function. The second digital learning object was on differentials and represented evaluating as the cognitive function. The last digital learning object was on areas by integration and represented analysis as the cognitive function. Throughout this paper the first digital learning object will be referred to as the Application DLO, the second digital learning object will be referred to as the Evaluation DLO and the third digital learning object will be referred to as the Analysis DLO. Each of these three digital learning objects represents a separate experiment within the overall study.

Participants

Digital learning objects can be used in online courses across all grade levels and all subjects which makes defining a target population difficult. However, if consideration is given to the need to create digital learning objects for a subject that better lends itself to embedding differential levels of feedback, then a defined population can be considered. For this study, the population was post-secondary engineering technology students who have a program entrance requirement of grade 12 mathematics and grade 12 physics or equivalent.

When determining the participants for this study, it was important to reduce the threat to internal validity and to increase power by selecting participants in a learning setting where there would be the least amount of diversity among the participants, that is, to ensure the sample is homogeneous in terms of entrance requirements. Consequently, this study examined a defined group of learners enrolled at a post-secondary institute. To minimize diversity in terms of entrance requirements among the participants, the participants were selected from first year students enrolled in introductory calculus courses as a requirement for engineering technology diploma programs. The participants were selected from several engineering programs that have the same program entrance requirements (grade 12 math and physics) and similar first year calculus courses. These programs included Chemical Engineering, Civil Engineering, Engineering Design and Drafting, Wireless Systems Engineering and Petroleum Engineering. Participants for this study were selected through convenience sampling from these programs using established groups in first year calculus classes. There were seven different engineering calculus classes that agreed to take part in the study with a total of 192 students. Of the 192 students in the seven classes, 145 consented to be participants in the study.

This study contains two independent variables, and is a two-way randomized groups, fixed effects design with sampling for the study being determined to maximize the power of the study. The first independent variable was levels of feedback. The differential levels of feedback were analyzed using a two-way randomized groups, fixed effects design with the independent variable and computer experience. The total sample size for this study was calculated using the G*Power statistical analysis software, and was determined to be 96 with a size of approximately 30 per treatment group (Faul, Erdfelder, Lang, & Buchner, 2007). The sample calculation was based on a postulated minimum detectable difference of 2% on post test scores with the α level set to a value of 0.05 and desired power ($1 - \beta$) set to 0.80 (Table 1). A 2% mean detectable difference was selected as it provides a conservative measure of detectable mean differences requiring a larger sample size.

Table 1: Sample Size Calculations

F tests – ANOVA: Fixed effects, omnibus, one–way

Analysis:	A priori: Compute required sample size		
Input:	Effect size f	=	0.3265986
α err prob	= 0.05		
Power (1–β err prob)	= .8		
Number of groups	= 3		
Output:	Noncentrality parameter λ	=	10.2399980
Critical F	= 3.0943374		
Numerator df	= 2		
Denominator df	= 93		
Total sample size	= 96		
Actual power	= 0.8118639		

Setting

This study was conducted at a Polytechnic Institute, in face to face calculus courses where all courses were first year calculus courses delivered in a 15 week semester. A Polytechnic is Post-Secondary Institute specializing in applied research and instruction in technical education and trades. While the regularly scheduled classes were face to face classes, participants were asked to participate in three one hour online lessons using the digital learning objects on three separate introductory calculus concepts. An important aspect to note is that the samples within each digital learning object group were unique to each group as few students participated in all three digital learning object groups. These lessons were delivered in a computer lab at the institute using digital learning objects designed specifically for this study by the researcher. The digital learning objects were integrated into the regularly scheduled activities of the class through an online Learning Management System. All students in the class were asked to complete the digital learning objects regardless of whether they consented to take part in the study. However, data was only collected for students who consented to take part in the study.

Research

This two-way randomized group, fixed effects design was selected to determine if learning is significantly different depending on the type of feedback embedded into a digital learning object with the second dimension being the learner characteristic of computer experience. In this study, the type of feedback was operationalized as differential levels of feedback with the levels of feedback designed specifically around the learning content. The first level only provided simple feedback to the participants' responses with only a correct or incorrect response as they worked through the learning material in the digital learning object. The second and third levels of feedback were elaborated feedback that are adaptive, or response contingent. The second level of feedback only gave positive feedback. Meaning that the adaptive feedback provided was only given for the correct response which described why the response was correct. The third level of feedback was also adaptive and addressed faulty interpretations. However, the third level of feedback only gave negative feedback. Meaning that the adaptive feedback provided was only given for incorrect responses which described why the response was incorrect.

This research design was chosen because it first allowed for the exploration of the relationship between a single categorical independent variable (level of feedback) and a single dependent variable for each of the three digital learning objects. The addition of the second categorical variable for learner characteristics also allowed for further exploration of the effect of differential levels of feedback in digital learning objects and whether the achievement on these levels is also affected by computer experience. In addition, a fixed effects design allows for selection of the levels of the Independent variables. To ensure that the groups were randomized, participants were selected from a number of post-secondary, first-year, engineering calculus classes using convenience sampling and then randomly placed into feedback conditions. Again, an important aspect to note is that the samples within each digital learning object group were unique to each group as few students completed all three digital learning objects. In placing participants within each of the feedback conditions, no regard was given to the type of engineering technology to control for the type of engineering program. In addition, to further control for the type of engineering program, participants were selected from engineering programs that have similar first year calculus courses and have similar program entrance requirements.

Procedures

The procedure for this study involved a number of steps. First, necessary approvals needed to be obtained from a number of stakeholders. Second, instructors needed to be asked to have students in their classes participate in the study and to have the digital learning objects to be used as part of the activities of the class for all students. Third, students needed to be asked to participate in the study and to use the results in the study (informed consent). Fourth, the study needed to be conducted with the participants. Fifth, the participants in the study had to provide re-consent for their data to be used in the study. Lastly, an analysis of the results was conducted and the final report completed.

Approvals

There were a number of stakeholders to gain approval from prior to conducting this research. The first was get approval from necessary research Ethics boards at the University where the researcher was completing the study and at the Polytechnic Institute where the data was being collected. The second set of approvals was from the leadership of the programs in which the research was being conducted.

Consent

Once approvals for the research was secured, the instructors were approached to provide consent to have students in their classes participate in the study by allowing the results from the participants' use of the digital learning objects to be used in the study. An Information and Consent letter outlining the background, purpose, procedures, risks, benefits of the study was made available to the instructors which included the timeline of the study, and the responsibilities of the instructors in the study (Appendix 1). The instructor was also asked to instruct the concepts that were covered in the digital learning objects. This instruction occurred after each digital learning object was presented to ensure that students were not disadvantaged by participation in the study. Based on the approvals and the participation of the instructors, seven classes of first year calculus students participated in the study.

Next, the researcher met with the students in each class and reviewed the consent forms to ask for their consent to use the data generated from their use of the digital learning objects and to sign the consent form (Appendix 2). Students were made aware that the use of the digital learning objects were a required elements of the course, and that they were only giving consent to use their data as part of the research study. During the meeting with the students, the procedures and timeline of the study were clearly outlined. Students were informed that there was no monetary or other reward for participating in the study, however, the benefits of using their data in the study to inform research into the effective design of online learning objects was described. Also, students were only informed of the independent variable of computer experience, but were not informed of the independent variable of differential levels of feedback embedded into the design of the digital learning objects since knowledge of the independent variable of levels of feedback would have potentially confounded the results of the study. Additionally, students were informed that any scores that they received on the assessment portion of the digital learning object would not be used in the final determination of their course mark and that their instructor would not have access to the results of study. To ensure that no student was disadvantaged, all students in the class were expected to complete the digital learning objects as a required element of the course, and the instructor was expected to re-teach all of the concepts presented in the study in a face to face setting. To protect privacy, students were informed that their anonymity would be protected throughout the study and that only the researcher would have access to the results. Furthermore, the students were informed that they could choose to withdraw from the study at any time up to the point where the data was anonymized at the conclusion of the data collection.

Re-consent

During the initial meeting with the students in the classes participating in the study, the students were asked to consent to have their data used in the study. Prior to consenting to participate in the study, the students were made aware that the study was designed to investigate the design of digital learning object and that computer experience was the factor being investigated. However, the students were not made aware of the Independent variable of differential levels of feedback in the digital learning objects before consenting to participate and were not made aware of the independent variable throughout the course of the study. This was to ensure that prior knowledge of the variable did not bias the results. Not disclosing the independent variable of differential levels of feedback meant that deception was used in the study. Consequently, at the end of the study, the researcher met with the participants in their classrooms and made them aware of the independent variable not previously disclosed and asked the participants to sign a re-consent form indicating that they were fully aware of all of the variables and wished to allow their data to remain in the study (Appendix 6). Some students were not in attendance during the classroom visit and were contacted through email. A total of four students who had originally consented to take part in the study could not be contacted for re-consent and their data was withdrawn from the study leaving a total of 141 participants in the student who had re-consented.

Data Gathering

Data from the study came from a number of sources, a pre-study survey, the digital learning objects (including post tests delivered in Moodle), and a post study survey.

The pre-study survey was a survey that only students who agreed to participate in the study completed. The survey (Appendix 3) included demographic questions, computer experience, and a questionnaire on computer attitude that was adapted from a standardized computer attitude survey by Nickell and Pinto (1986).

The digital learning objects provided the second source of data. There were three separate digital learning objects created for three different independent calculus topics. As stated earlier, the three digital learning objects were Application DLO which was on the topic of related rates, Evaluation DLO which was on the topic of differentials, and Analysis DLO which was on the topic of areas by integration. Participants completed each one hour session in a computer lab monitored by their class instructor. Each digital learning object captured two sets of data points that were collected by way of a Learning Management System as described in the delivery method section below. The first data point for the digital learning objects determined the time spent on task on each of the two parts of the digital learning object which was the lesson and guided practice. The digital learning objects were programmed to record the time that the participant took to complete the lesson and the guided practice portions of the digital learning objects. When the participants completed the digital learning objects, they were presented with the times they took to complete the lesson and the guided practice portions and asked to write down the times and record them in the first two questions in the post-test (Figure 2).

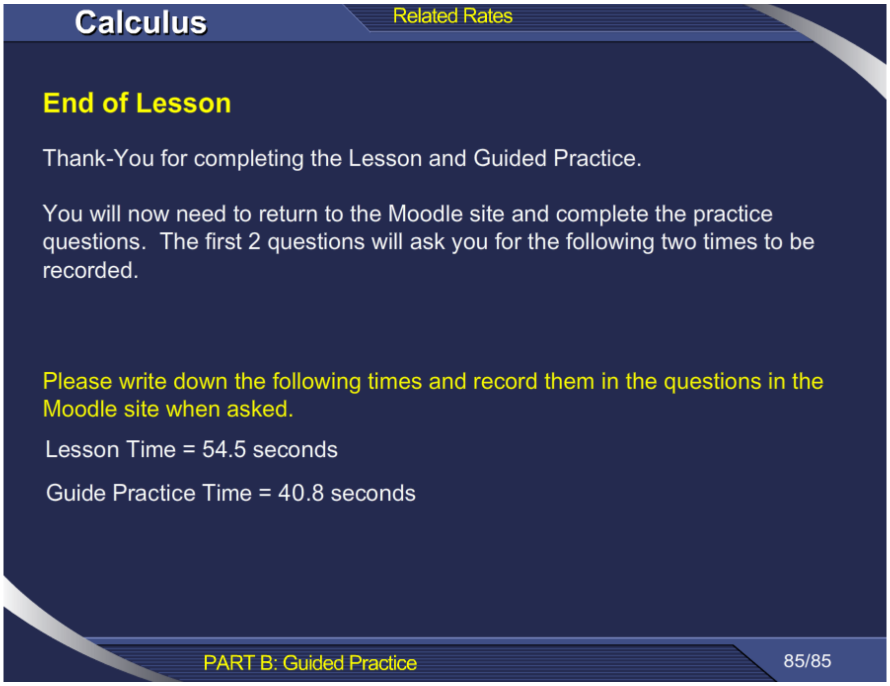


Figure 2: Lesson Time/Screen Time Screen Shot

The second set of data points for each of the digital learning objects was captured by way of a multiple choice test at the end of each of the digital learning objects which measured learning as the dependent variable for this study. Each multiple choice test was specific to the content of the digital learning object it was associated with, and were developed based on the question presented in the lesson and guided practice portions of the digital learning objects.

The addition data source was the post-study survey which was a survey that only participants in the study completed. The post-study survey was an open ended question on the participants' perceived usefulness of the learning objects.

Design of the Digital Learning Objects

In total, three digital learning objects were created for the study and they were each designed with a lesson and guided practice portion. Essentially, three separate experiments were conducted using three separate learning objects each with their own associated post questions unique to that learning object. To determine which topics to select for the study, each instructor was asked to provide a list of topics and their class timeline for each of the seven classes participating in the study. From the list, 12 potential topics were selected that were common to all three courses and were independent of one another. That is, no learning in one object was dependent on the learning found in another and represented a different cognitive function (Bloom et al., 1956). Eight of the topics were to be taught in the first month of the course which did not give sufficient time to develop the digital learning objects and pre and post tests. Of the four remaining topics, three were identified by the instructors as the best choices for the study in terms of timing with their class schedules. These topics were related rates, differentials, and areas by integration. These three topics were determined to be independent of one another and are commonly taught in any order and one, two or all three can be taught to students.

The design of the digital learning objects for each topic was identical in all aspects other than the treatment of differential levels of feedback. Each digital learning object was designed using Adobe Flash software and was delivered via the internet using the Moodle Learning Management system (LMS). Five modules were created for each participant in Moodle. The first module contained the pre-study survey, the second, third and fourth modules contained the digital learning objects (including post tests) and the fifth module contained the post-study survey. Both the pre and post study surveys were identical for all participants.

The design of each digital learning object was developed with two parts, the lesson and the guided practice. The lesson part of the digital learning objects was identical for all participants. However, the guided practice parts varied by participant depending upon which treatment condition they were part of. That is, the guided practice provided simple feedback, positive feedback or negative feedback for all questions depending on the treatment condition.

The lesson portion of the digital learning objects presented a brief explanation or lesson which included animations or interactive objects as necessary to teach the topic. Additionally, each lesson also included two or three worked examples of problems with explanations for each step as appropriate. For example, the following two graphics show the interactive object portion of the lesson on differentials from the Evaluation DLO where the participant was able explore the relationship between dy and Δy as the value of Δx is manipulated by the participant (Figure 3and Figure 4). The results are shown to the participant both graphically and numerically. As the participant manipulated the value for Δx, the graph changed accordingly and the new calculated values of dy and Δy were displayed. Explanations were also dynamically changed depending on the value of Δx.

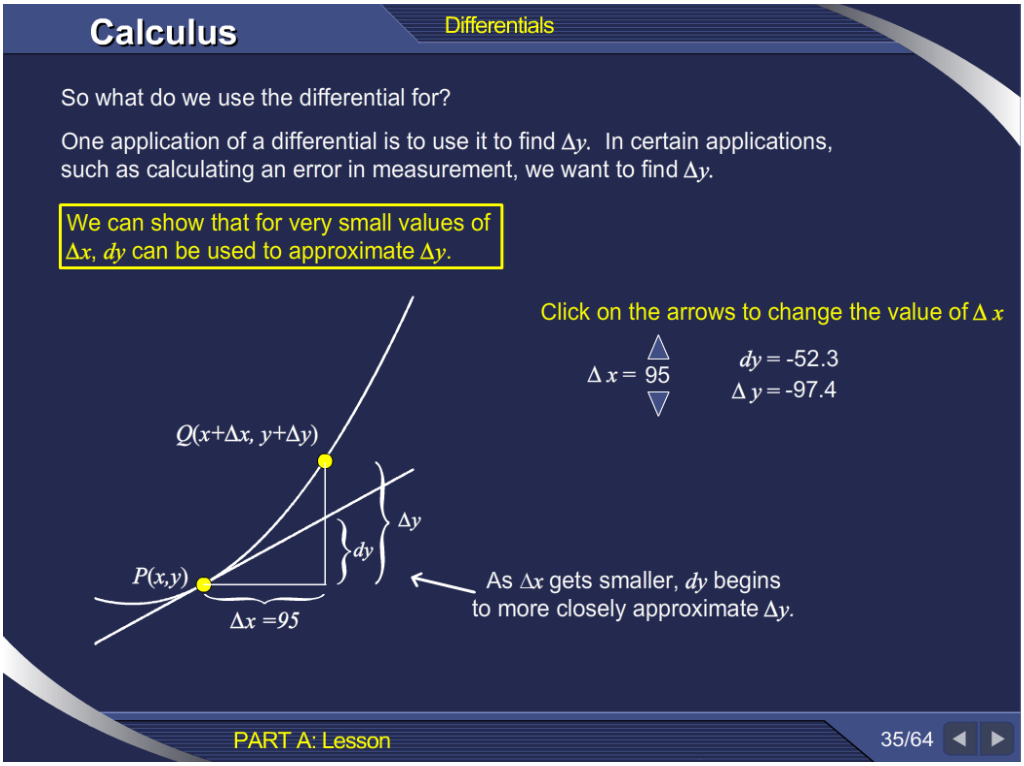


Figure 3: Differentials Interactive Object - Part 1

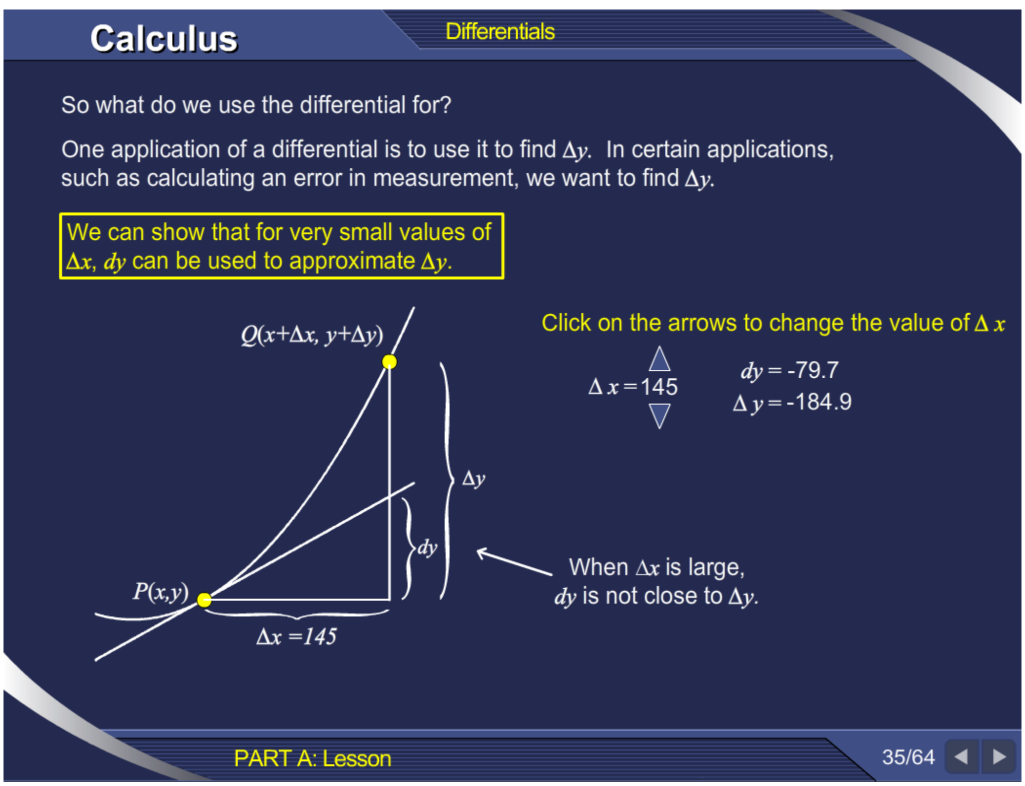


Figure 4: Differentials Interactive Object – Part 2

The lesson portion of the digital learning objects also included worked examples with explanations and, where appropriate, the steps to solve, illustrations and animations were included. Figure 5, Figure 6, Figure 7, and Figure 8 show four parts of a worked example in the lesson on Area by integration which was the Analysis DLO.

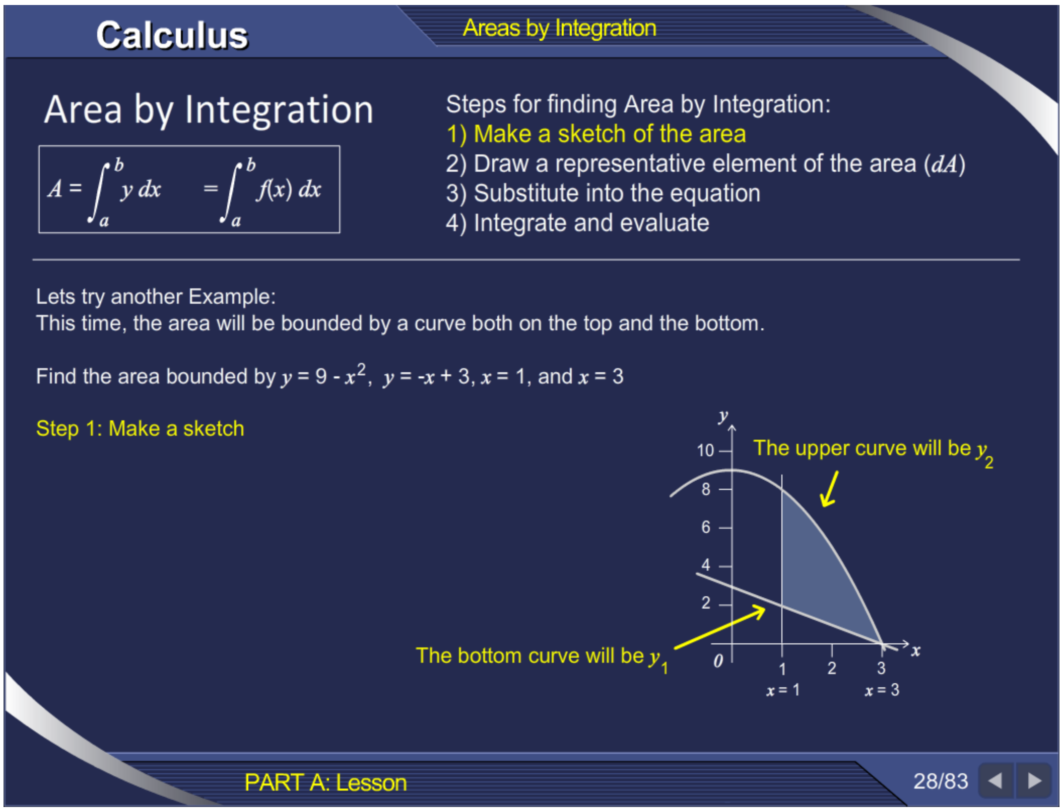


Figure 5: Areas by Integration example - part 1

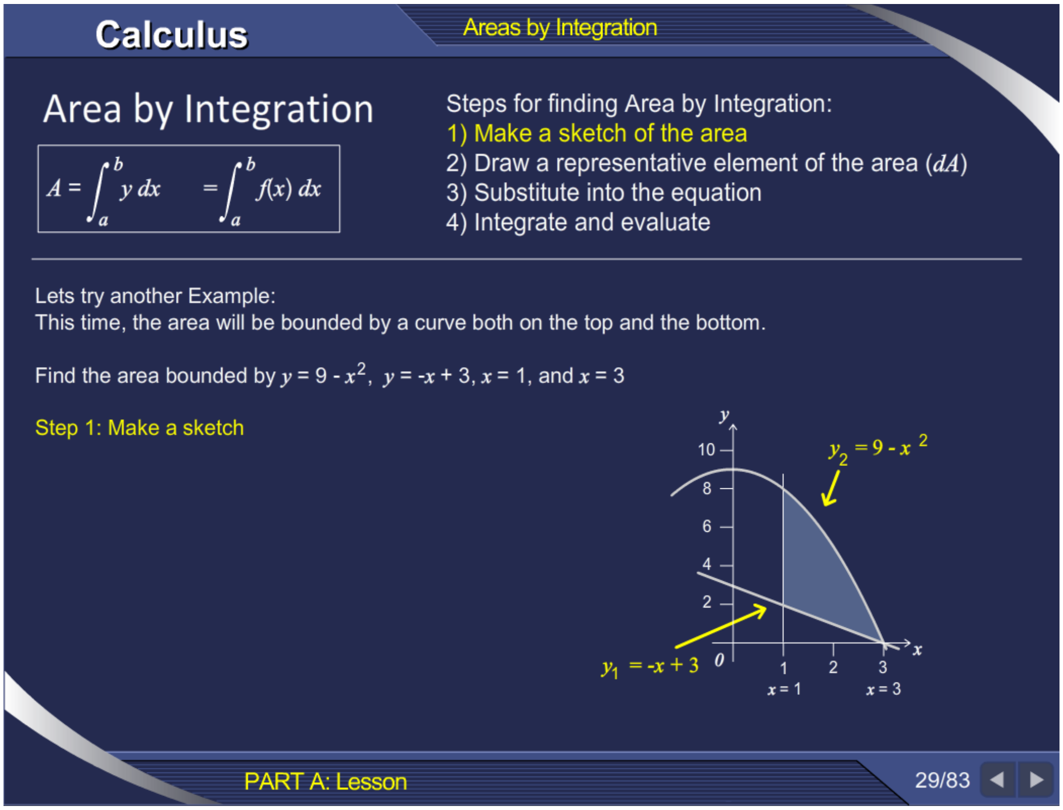


Figure 6: Areas by Integration example - part 2

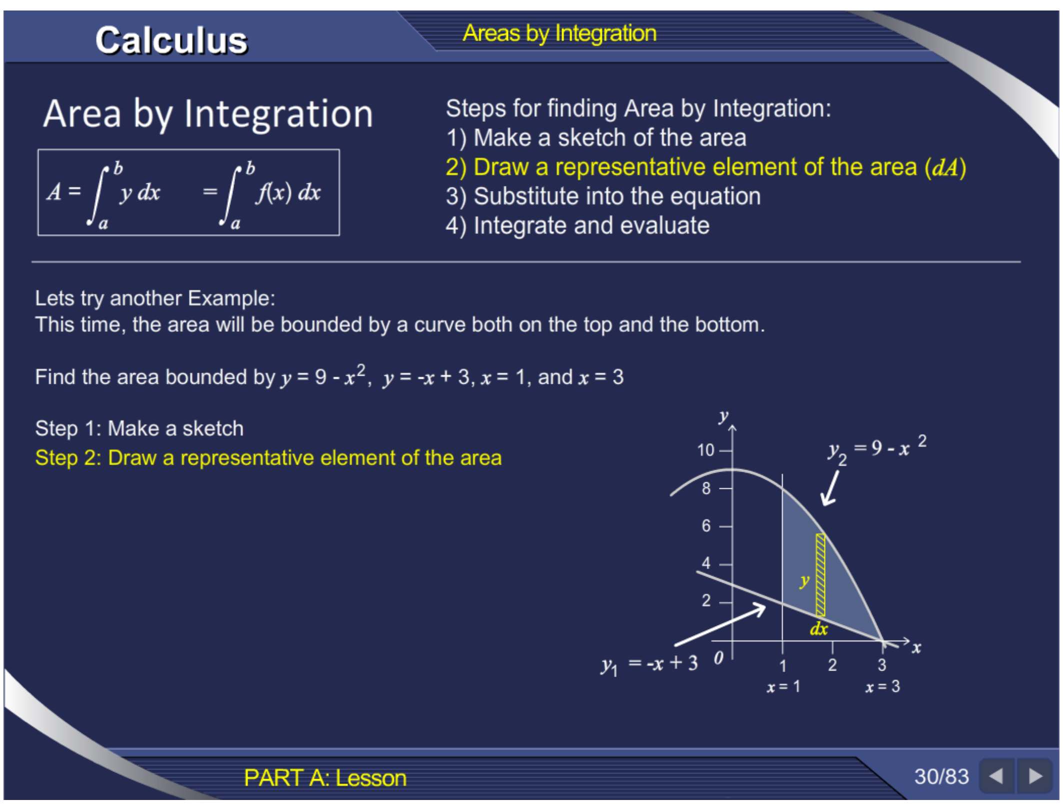


Figure 7 Areas by Integration example - part 3

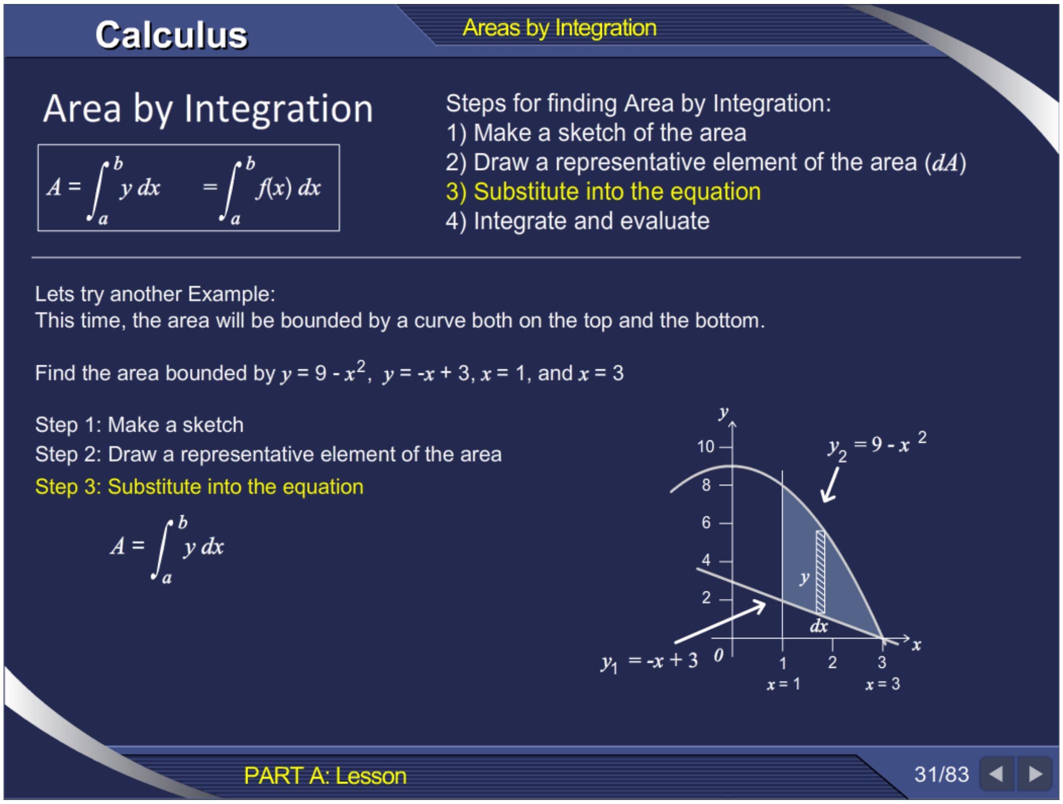


Figure 8: Areas by Integration example - part 4

The second part in each of the digital learning objects was the guided practice section. In the guided practice section, the participants were presented with a problem based on the learning from the lesson. As the participants worked through the problem in the guided practice, they were asked to answer multiple choice questions at each step through the problem. For each digital learning object, the guided practice section was identical for all participants except for the feedback they received when they answered the multiple choice questions. Depending on the treatment condition the participants were assigned to, they received simple feedback, positive feedback or negative feedback. The digital learning objects with simple feedback did not provide feedback to the participants when they answered the questions other than a simple “correct” or “incorrect.” The digital learning objects with positive feedback provided feedback which explained why their answer was correct, and the digital learning objects with negative feedback provided feedback which explained why their answer was incorrect. In designing the feedback for the digital learning objects with negative and positive feedback, it was important to ensure that the feedback provided did not provide new information to the participant that was not presented in the lesson portion of the digital learning object. Otherwise, it would be impossible to determine whether any significant difference in learning was the result of the new learning presented in the feedback or from the presence or absence of positive and negative feedback. Figure 9, Figure 10, and Figure 11 show an example guided practice question for the Analysis DLO which was on the topic of area by integration. The correct response to the question in the learning object was "vertical." Figure 9 is a screen shot from the digital learning object with simple feedback embedded. When the correct answer is selected, the response "correct" is displayed, and when an incorrect response is selected, the response "incorrect" is displayed. Figure 10 is a screen shot from the digital learning object with positive feedback. When the correct answer is selected, feedback that explains why the answer was correct is displayed. If any incorrect response was selected then the response "incorrect" is displayed. Figure 11 is a screen shot from the digital learning object with negative feedback. When the incorrect answer is selected, feedback that explains why the answer was incorrect is displayed. If any correct response was selected then the response "correct" is displayed.

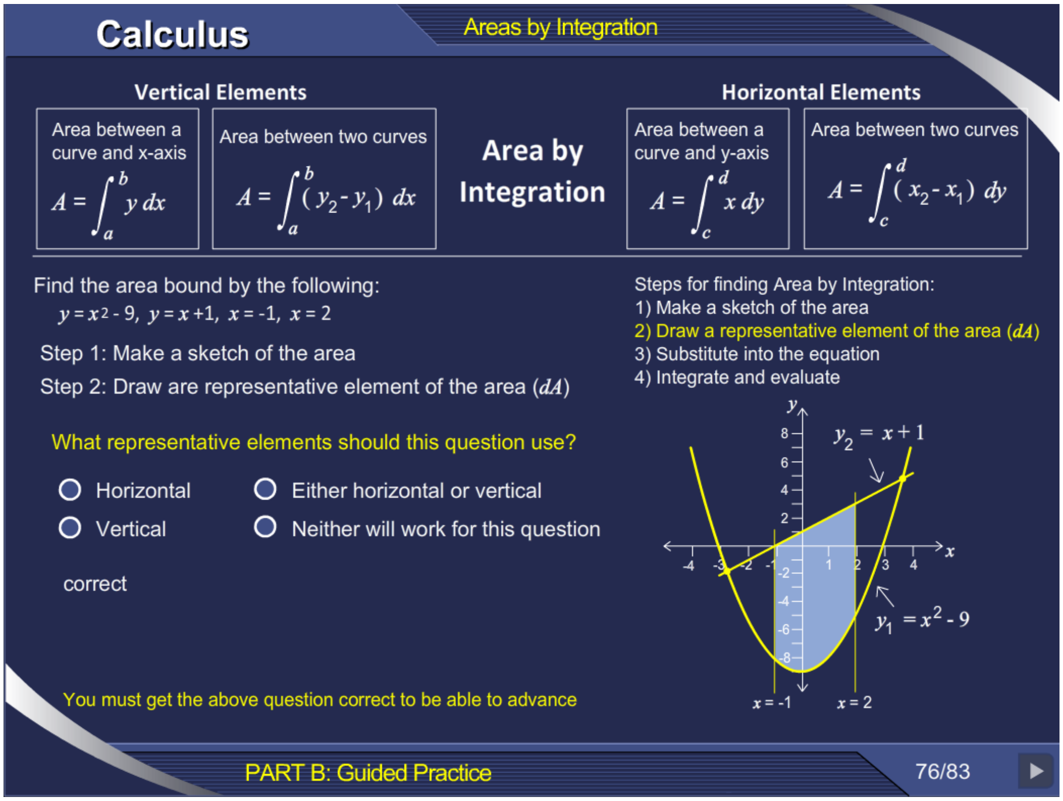


Figure 9: Simple Feedback example

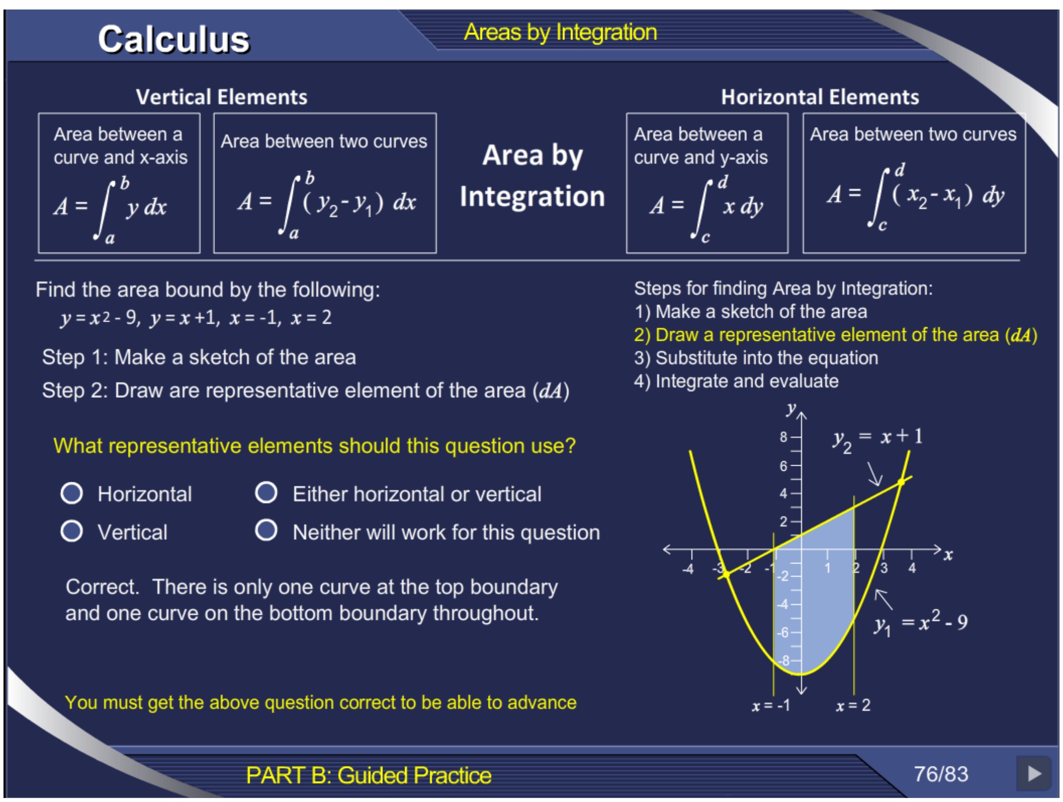


Figure 10: Positive feedback example

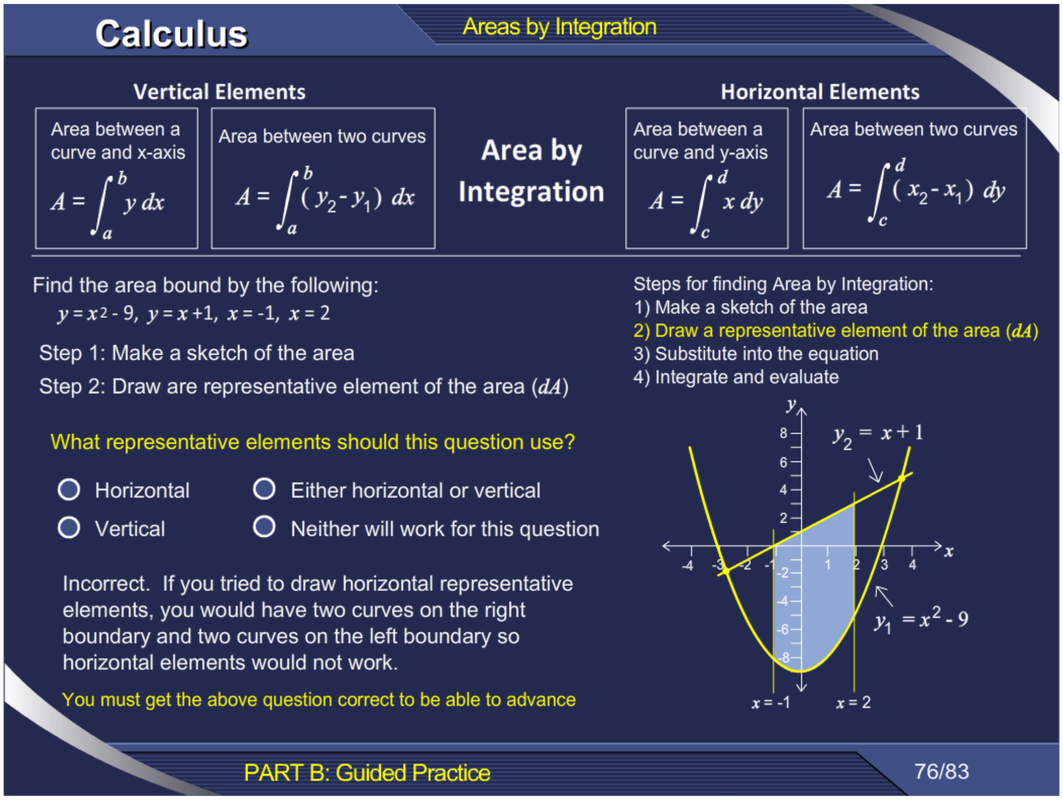


Figure 11: Negative feedback example

Delivery method

Moodle was selected as the delivery platform for the study since all participants in the study used Moodle in every course in their program of studies and were highly familiar with the Moodle Learning Management System which helped to reduce any affect that varying degrees of familiarity with the delivery mode may have on reliability. Additionally, the Moodle Learning Management System allowed for ease of set up and delivery of the digital learning objects, quizzes and surveys which also included functionality to support the set up and delivery of the learning objects by treatment condition.

In total, five modules were created for each class in Moodle. The first module delivered the pre-study questionnaire (Figure 12), the second, third and fourth modules delivered the three digital learning objects along with the pre-tests and quizzes (

Figure 13), and the fifth module delivered the post-study survey (Figure 14).

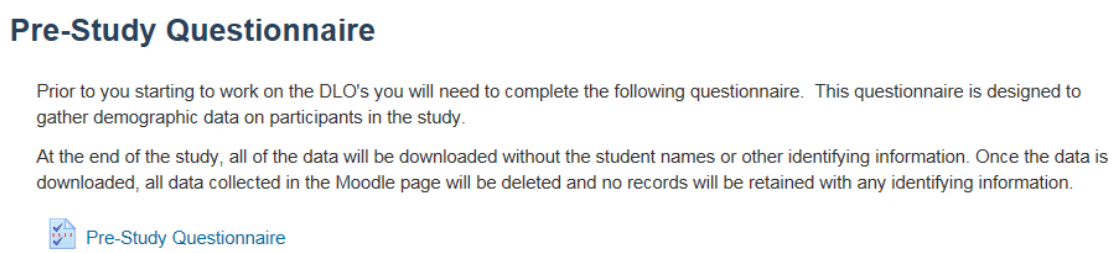


Figure 12: Pre-Study Questionnaire module

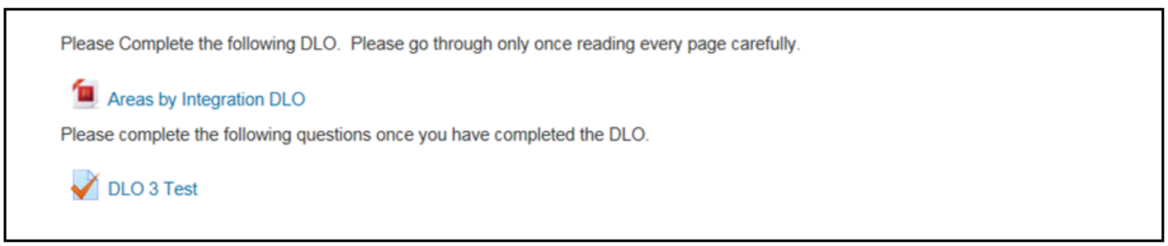


Figure 13: Digital learning object module

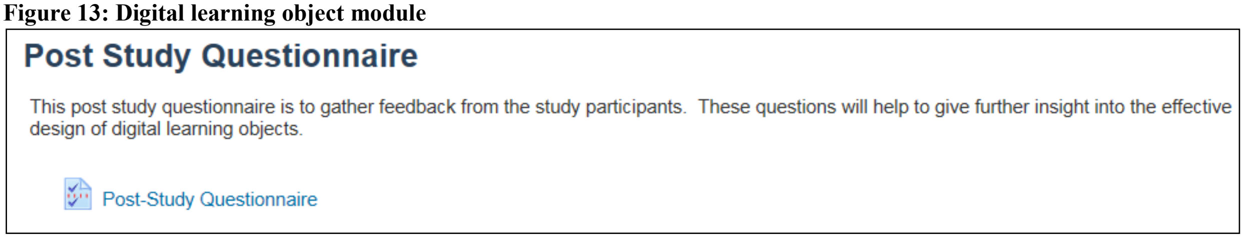


Figure 14: Post - study questionnaire module

The three digital learning modules (

Figure 13) contained not only the post-tests, but also all four versions of the digital learning objects (non-participants, simple feedback positive feedback, and negative feedback). Group functionality within the Moodle Learning Management System allowed for the placement of participants into a group that represented one of the treatment conditions or a non-participant group. The digital learning object that was made available to the participant was dependent upon which group in Moodle the participant was placed into. However, the form of the pre-test and post-test were identical for all digital learning object groups. Participants were not able to determine which treatment condition they were in since names of all the versions of the digital learning objects were the same, and in fact, the participants were not aware that there were different treatment conditions.

The researcher determined the best date and time for each of the seven classes participating in the study to complete the digital learning objects in collaboration with the course instructors. A computer lab was scheduled for a one hour time period and all of the class participants in the class participated in using the digital learning object during the scheduled period. Non-participants in the study still completed the learning material, but they were put into a different group with a different digital learning object and a note was displayed on the Moodle page reminding them that their data was not being collected. It was expected that the participants completed the digital learning objects as part of the normal part of their classroom activities. As such, the researcher was only available for the beginning of the class period, to troubleshoot as needed. The Moodle Learning Management System also allowed the researcher to activate or deactivate the modules as needed. For each of the learning sessions, the researcher activated the modules just prior to the start of the class and deactivated them at the end of the class. It should also be noted that not all participants were able to complete all three digital learning objects since the learning objects were three distinct modules presented at different times. Consequently, most of participants were absent for one or more of the sessions and were unable to complete. This meant that the sample varied from learning object to learning object. However, as already stated this study considered each learning object as a distinct case with different post tests. With no dependencies between the learning object content and differing samples, the results from each learning object were analyzed independently, as a separate sample, using an Analysis of Variance (ANOVA) for each.

Summary of the Procedure

For this study, there was one Moodle site created for each of the seven classes participating in the study. Five modules were created in Moodle for the participants to complete through the course of the study. The first Moodle module delivered the pre-study survey and the fifth Moodle module delivered the post-study survey. Moodle modules two through four represented the three different Moodle Modules that contained the digital learning objects and the post-tests designed to test the content of the digital learning objects. Module two contained the digital learning object on related rates in Calculus along with a post test for related rates, module three contained the learning object on differentials along with a post test for differentials, and module four contained a digital learning object for areas by integration along with a post-test for area by integration. All students who agreed to participate in the study were randomly assigned into one of the three feedback conditions of simple feedback, positive feedback and negative feedback. For each of the learning objects, participants were presented with a learning object that was dependent upon the feedback condition they were in. For example, for Moodle module two, the Evaluation DLO was on the topic of related rates and three learning objects were created for related rates that were identical except for the type of feedback embedded into the learning object. The learning object that the participant received was dependent upon the treatment condition the participant was placed in. A participant was assigned to the same feedback condition for all of the digital learning objects he/she completed. Figure 15 shows the structure of Moodle module two for the Application DLO (related rates).

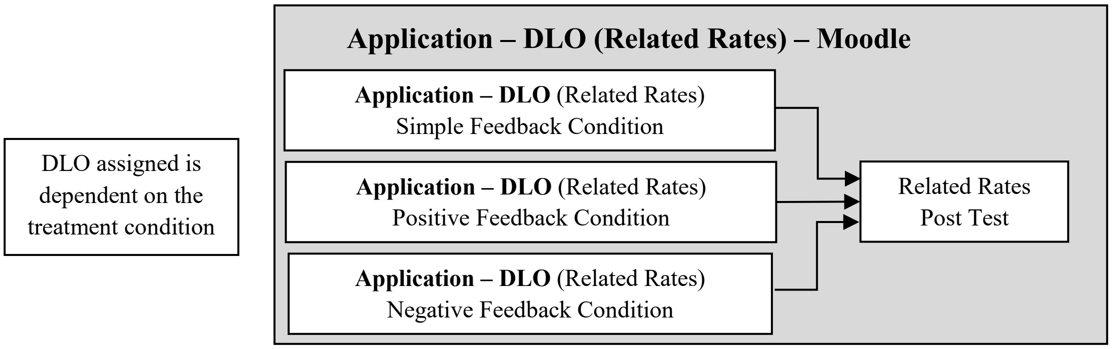


Figure 15: Structure of Moodle Module

Not all participants were able to complete modules two through four which contained the digital learning objects since the modules were delivered on separate dates. Consequently, participants may have completed one, two, or three of the modules containing the digital learning objects dependent on their availability.

Participants who did not consent to participate in the study were given the digital learning object with simple feedback to complete and were not presented with the pre-study survey or the post study survey and no data was collected. All participants had the same pre-study survey and post-study survey regardless of the treatment condition they were part of.

The actual digital learning objects were structured in two parts. The first part was a lesson that was a demonstration of the theory with no interaction other than allowing the participant to advance through the lesson at their own pace. The second part was guided practice which allowed the participants to work through the problem and provide answers to questions at each step. Different types of feedback were provided to the participants during the guided practice part of the digital learning object with the feedback determined by the assigned feedback condition. The lesson itself was the same for all participants. Only the guided practice varied depending on the feedback condition as the guided practice part contained the different levels of feedback.

Data Analysis

A one-way analysis of variance (ANOVA) was used for each digital learning object separately to initially analyze the results for the levels of feedback using a *p*-value with a level of significance of <0.05. Further two-way univariate analyses of variance (ANOVA) were used to analyze the results for the computer experience independent variable. A two way analysis of variance was chosen as all of the independent variables in the study were categorical. Consideration was given to using an analysis of covariance (ANCOVA) instead of a two-way ANOVA design, however, an ANCOVA design requires one of the independent variables to be categorical and one of the independent variables to be continuous. This is because ANCOVA is a linear model blending both ANOVA and regression. Without a continuous independent variable a regression model cannot be run and ANCOVA is not a possible method of analysis.

The two-way analyses were only run if the distribution of the sample sizes for the independent variables allowed for statistical analysis. If sample sizes warranted, a two-way ANOVA was used to compare differential levels of feedback with each of the individual different independent variables and post-hoc tests were conducted as appropriate.

Assumptions and Limitations

One of the assumptions in this study is that all of the participants who have the same level of experience with the topics will have the same current knowledge. That is, participants whose prior knowledge is identified as having completed grade 12 math and physics courses may not necessarily be at the same current level of ability. This is because the time between completing their grade 12 math and physics courses and when the participant begins post-secondary studies varies significantly. Additionally, simply completing a high school math and physics course may not always be an indicator of success in a post-secondary calculus class.

Another potential limitation of the study is that there many not be a homogenous sample in terms of computer experience. As Kay and Knaack (2008b) note, the differences in computer experience that existed in the past are currently not as pronounced since computers are now consistently used at a secondary school level. Consequently, depending on the distribution of the participants' computer experience, statistical analysis may not be possible as sample sizes may be insufficient.

CHAPTER FOUR – FINDINGS

Introduction

In this study, the purpose was to investigate the effect on student achievement scores of student driven feedback embedded in digital learning objects designed for post-secondary calculus students. The effectiveness of the feedback was determined by examining the effect of differential levels of elaborated feedback embedded into the digital learning objects. Effect of the feedback was determined by comparing post-test scores of the different feedback conditions to determine if there was a statistically significant difference in learning between the feedback conditions. Additionally, the effect of embedded feedback was investigated in relation to learner characteristics. Learner characteristics were measured in a number of ways, primarily in terms of computer experience. Other measures of learner characteristics were also determined which included demographic data as well as time on task while completing the lesson and guided practice sections of the digital learning object. While these additional measures of learner characteristics such as age and gender were not included in the research question, the data was readily accessible and collected. These additional characteristics were easily analyzed for potential opportunities for further research. Data collection methods and analysis of the data is presented in this chapter along with a discussion of the reliability and validity of the findings. Additionally, results from the additional comments question at the end of the post study survey are summarized and presented.

Demographic Data

A total of 145 engineering students, enrolled in seven different 1st year calculus classes consented to participate in the study, however, only 141 participants re-consented to participate as four participants could not be contacted for re-consent. The demographic data was collected in the pre-study questionnaire, and of the 141 students participating in the study, only 105 participants chose to complete the pre-study questionnaire which was comprised of demographic questions, questions on previous math experience, and questions on computer experience. Two demographic questions were also asked in the questionnaire which were age and gender. While age and gender were not directly identified as variables in the study, age and gender were identified as possible considerations in the literature in terms of computer attitude. Kay and Knaack (2008b) noted that males tended to have much more positive attitudes and higher ability in respect to computer use, and age is a significant factor in both attitude and performance in regards to digital learning objects. They also found that post-secondary students performed significantly better and had a more positive attitude than secondary students.

In terms of age, the majority of the participants who provided demographic data were age 26 or less with only 11 participants (10%) 27 years of age or older. Participants 27 or older ranged in age from 27 – 44. Of the participants who were age 26 or less, 52 of the participants (50%) were in the range of 18-20, 21 participants (20%) were in the range 21-23, and 21 participants (20%) were in the range 24-26 (**Error! Reference source not found.**). The full d istribution of ages is shown in the graph in Figure 16: Age Distribution.

Table 2: Age Distribution

Age	*Count*	*%*
18-20	52	50%
21-23	21	20%
24-26	21	20%
27-29	4	4%
30-32	3	3%
33-35	1	1%
36-38	2	2%
>38	1	1%
Total	105	100%

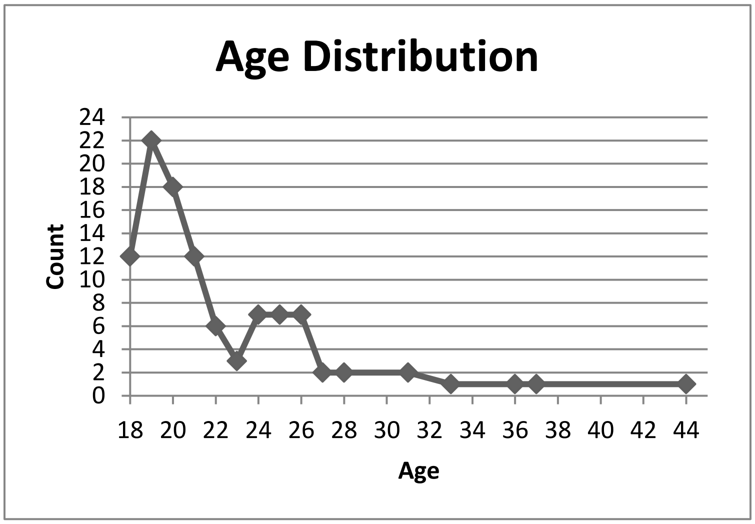


Figure 16: Age Distribution

Gender was also determined with males being over-represented in the sample comprising 75% of the total (Table 3: Gender).

Table 3: Gender

Gender	*Total*
Male	79
Female	26
Total	105

Tests and Data Collection Methods

All of the data in the study was collected using surveys and tests in the Moodle Learning Management System. As already noted, Moodle was selected because it was the Learning Management System used by the Institute for all course delivery and all of the participants were familiar with the use and functionality of Moodle. The Moodle Learning Management System was also selected because it included functionality that supported the delivery of the digital learning objects by treatment condition as well as easy setup and administration of the surveys and tests.

The study involved two independent variables which was determined using the pre-study survey, the task matching questions, and the post-test.

The first independent variable was defined as the type of feedback which was embedded into each of three digital learning objects. The levels of feedback were defined as simple feedback, positive feedback and negative feedback with positive and negative feedback being response contingent elaborative feedback (Shute, 2008; Van der Kleij, Feskens & Eggen, 2015).

The other independent variable was computer experience and was determined by way of a pre-study survey. The pre-study survey (Appendix 3) was a brief survey that the participants answered at the beginning of the study that was used to determine the participant's age, gender, and computer experience. Computer experience was determined by a series of questions on the survey that looked at the participants past and current use of computers in the areas of social media use, experience with online courses, video game uses and self reported level of computer experience questions. Additionally, computer attitude was determined using the Computer Attitude Scale developed by Nickell & Pinto (1986). The Computer Attitude Scale is a series of 20 psychometrically tested questions that returns an overall computer attitude score between 20 and 100 with 20 indicating a strong negative attitude towards computers and 100 indicating a strong positive attitude towards computers.

The dependent variable was measured as the participants' scores on the post-test. The post-test (Appendix 4) consisted of multiple choice questions developed for each digital learning object to measure learning. Each test was also set up and delivered using the Moodle Learning Management System which allowed for easy delivery of the questions to all of the participants as well as providing statistical analysis of the questions. All of the questions were designed to test the learning of the concepts presented in the digital learning objects. Additionally, the first two questions in each post test were not scored, and were instead used to capture the time on task by asking the participants to record the times taken to complete the lesson and guided practice portions of the digital learning object.

The Moodle Learning Management System also allowed for easy export of the data into excel while also calculating statistics for reliability of the tests. **Error! Reference source not found.** below represents the summary analysis of the three post-tests provided by Moodle.

Table 5 is a summary of the statistical analysis provided at the question level for the post-test questions for each of the digital learning objects. The discriminative index was calculated by Moodle which determines a correlation between the test question and the participants score on the quiz. For both digital learning object one and digital learning object two the discriminative index was at reasonable levels for the majority of the questions with the exception of question four for digital learning object two which had a discriminative index of 0.09. For the third DLO which was the Analysis DLO, there were a number of questions with a low discriminative index which may indicate that the test questions were potentially too easy or too difficult which contributed to a low level of correlation between the question score and the test score. This is supported by examining the facility index which determines the percent of participants who correctly answered the question. The questions with the lowest discriminative indices were also the questions that had the higher or lowest facility index scores. Additionally, the questions themselves may be poorly worded which may have led to the misinterpretations or misunderstanding. While a low discriminative index score doesn't necessarily mean that the test or questions are poorly written, it does suggest that the questions should be examined to ensure that they are well written and not ambiguous. In many cases the questions may be purposefully written so that they are either easy or difficult. Question six for the Analysis DLO had a negative discriminative index. Although the value is low, the negative correlation indicates that those who did well on the test did poorly on this question. A close examination of the question indicates that there was nothing that would indicate that this question was poorly written or didn't test what was intended. In fact, the wording on the question was identical to two other questions (5 and 7) except for the diagram. This may also indicate that the explanations in the digital learning objects may have led to a misunderstanding.

Table 4: Post test summary analysis

Digital Learning Object	*Number of attempts*	*Average grade*	*Median grade*	*Standard deviation*
Application DLO	148	76.2%	83.0%	24.9%
Evaluation DLO	117	72.7%	78.5%	23.8%
Analysis DLO	120	62.0%	67.4%	19.2%

Table 5: Post test question analysis

Digital Learning Object	*Question number*	*Facility index*	*Intended weight*	*Effective weight*	*Discrimination index*
Application DLO	1	89.9%	10.0%	8.0%	0.3335
	2	89.2%	10.0%	7.2%	0.2698
	3	87.2%	10.0%	9.5%	0.3740
	4	66.2%	20.0%	22.2%	0.4945
	5	78.4%	10.0%	12.5%	0.3984
	6	77.0%	20.0%	20.3%	0.4598
	7	65.5%	20.0%	20.3%	0.3287
Evaluation DLO	1	78.6%	11.1%	10.8%	0.4569
	2	71.8%	11.1%	11.7%	0.4339
	3	70.9%	11.1%	10.6%	0.3529
	4	88.9%	11.1%	6.0%	0.0977
	5	73.5%	11.1%	10.5%	0.3803
	6	60.7%	11.1%	12.6%	0.4941
	7	76.1%	11.1%	10.8%	0.3831
	8	66.7%	11.1%	13.7%	0.6143
	9	67.5%	11.1%	13.1%	0.5270
Analysis DLO	1	81.7%	14.3%	15.1%	0.3212
	2	84.2%	14.3%	15.3%	0.3516
	3	42.5%	14.3%	17.2%	0.1147
	4	90.8%	14.3%	8.9%	0.0542
	5	57.5%	14.3%	18.1%	0.2021
	6	22.5%	14.3%	6.3%	-0.1920
	7	55.0%	14.3%	19.1%	0.2928

At the conclusion of the study, each participant was asked to complete a short survey comprising of a single open-ended comment box. The survey question was designed to determine the experience the participants had using the digital learning objects.

Missing Data

In total, there were 141 students who participated in the study. There were 48 students in the simple feedback condition, 45 students in the negative feedback condition and 48 students in the positive feedback condition. All of the participants were asked to complete the pre-test and post-test surveys. However, the participants were not required to complete the surveys so a number of participants chose not to complete the surveys. Additionally, when the pre-test survey was administered to the first group of participants, it was determined that the labelling on the likert scales for the survey were incorrectly labelled, consequently the entire survey for that group had to be removed from the data set. This accounted for 14 incomplete pre-study surveys. Consequently, 105 of the 141 participants completed the pre-test surveys. The post-test surveys had a much lower completion rate with only 56 participants completing the survey. This is possibly because the last digital learning objects were delivered in the final two weeks of class with just enough time for the participants to complete the digital learning objects and the test. The participants were instructed by their teacher to complete the post-test survey on their own time, however, many did not do so.

For the post-tests for the digital learning objects, there was also missing data with a number of factors contributing to the missing data. First, participants were not required to complete the test after they completed the digital learning objects; however, the number who selected not to complete the test was very low as almost all of the participants who were present in class to complete the digital learning objects also completed the tests. The majority of the participants who did not complete the post-tests did not attend the sessions for the digital learning objects and so did not complete the digital learning objects. While a number of factors may have contributed to the reasons for the participants not attending for one or more of the three sessions for the digital learning objects; the primary reason was provided by the instructors. That is, for a number of the scheduled sessions for the digital learning objects, the participants had assignments due or major exams on the same day in the days following. This resulted in a number of the participants electing not to participate in one or more of the sessions because of conflicting priorities. At the end of the study, 119 participants completed the post-test for the Application DLO, 98 participants completed the post-test for the Evaluation DLO, and 103 participants completed the post-test for the Analysis DLO.

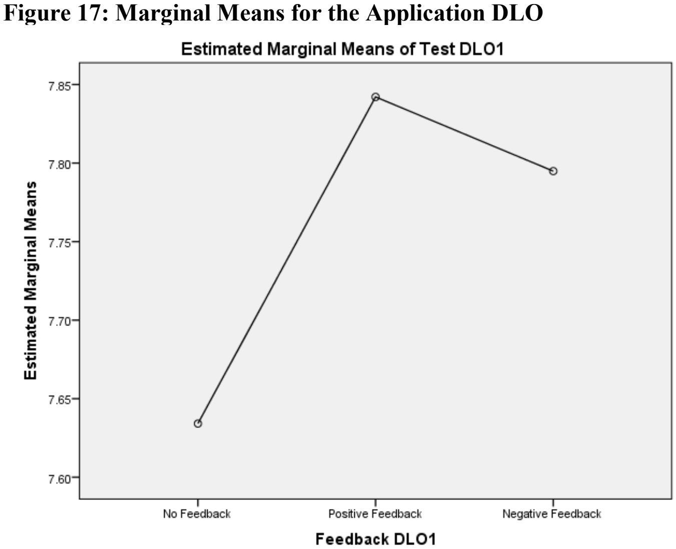
Finding – Independent Variable 1: Difference in learning based on the levels of feedback

The results of the post-test for each of the digital learning objects were first analyzed using only the type of feedback as the independent variable and the scores on the post tests as the dependent variable. For this first analysis, no consideration was given to computer experience. The results for type of feedback were analyzed using a fixed effect, one-way randomized groups, analysis of variance (ANOVA). Omnibus tests were completed for each digital learning object separately followed by post hoc pair wise comparisons. To determine if pair wise comparisons were appropriate to conduct, p values of <0.1 were used to as determining factor. This is in alignment with Simon (2006) who suggests that p values of $>= 0.05$ and <0.1 indicate that there is suggestive evidence against the null hypothesis. Suggestive evidence is not used as an indication of statistically significant results; instead it is used as a determining factor to conduct further analysis.

Application DLO (Related Rates)

An analysis of variance for the results of the Application DLO found no significant main effect for the type of feedback (simple feedback, positive feedback, negative feedback) for the participants score in a post-test at a p <0.05 level for the three levels of feedback F(2,115) = .072, p = .93, η_p^2= .001. Additionally, Levene's test of homogeneity of variance indicated unequal variances (F = 6.03, p = 0.003) so post hoc pair wise comparisons were conducted using the Dunnett T3 test (Tabachnick & Fidell, 2007). Results of Dunnett's T3 indicated that test scores for the simple feedback condition did not differ significantly from test scores with positive feedback condition (p = .98) and from test scores with negative feedback condition (p = .99). Test scores from the positive feedback condition also did not differ significantly from the test scores from the negative feedback condition (p = 1.00). A means plot below represents the marginal means of the test scores for the Application DLO.

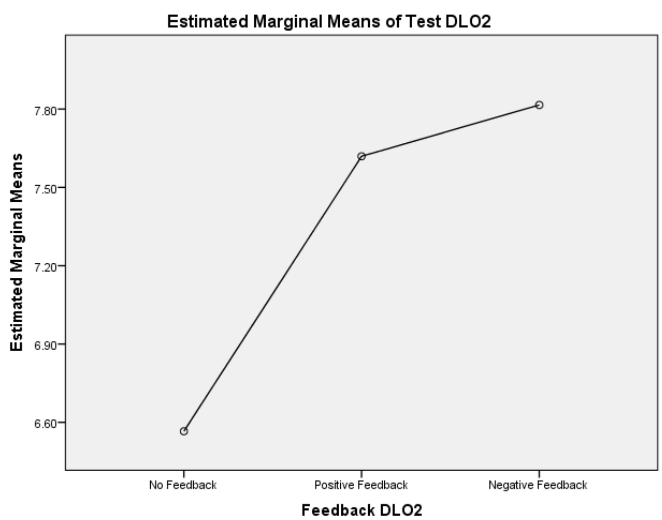
Figure 17: Marginal Means for the Application DLO



Evaluation DLO (Differentials)

An analysis of variance for the results of the Evaluation DLO found no significant main effect for the type of feedback (simple feedback, positive feedback, negative feedback) for the participants score in a post-test at a p <0.05 level for the three levels of feedback $F(2,95) = 2.00$, $p = .14$, $\eta_p^2 = .040$. Levene's test of homogeneity of variance indicated equal variances ($F = 1.05$, $p = 0.35$) so post hoc pair wise comparisons were conducted using the Tukey HSD test (Tabachnick & Fidell, 2007). Results of Tukey HSD indicated that test scores for the simple feedback condition did not differ significantly from test scores with positive feedback condition ($p = .25$) and from test scores with negative feedback condition ($p = .17$). Test scores from the positive feedback condition also did not differ significantly from the test scores from the negative feedback condition ($p = .954$). A means plot below represents the marginal means of the test scores for the Evaluation DLO.

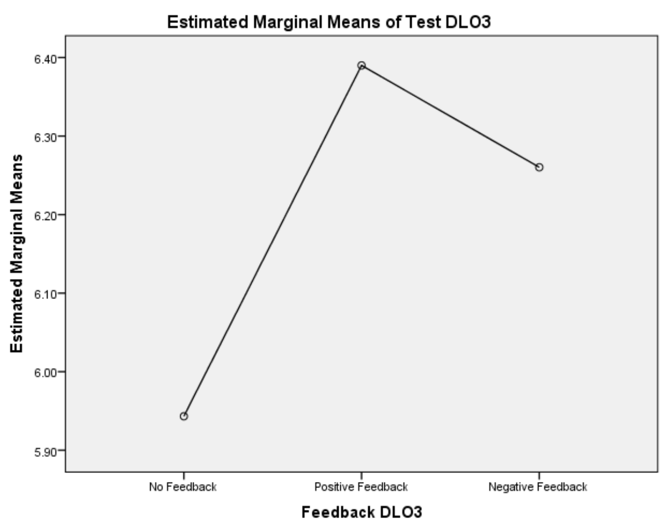
Figure 18: Marginal Means for the Evaluation DLO



Analysis DLO (Areas by Integration)

An analysis of variance for the results of the Analysis DLO found no significant main effect for the type of feedback (simple feedback, positive feedback, negative feedback) for the participants score in a post-test at a $p < 0.05$ level for the three levels of feedback $F(2,100) = .45$, $p = .64$, $\eta_p^2 = .009$. Levene's test of homogeneity of variance indicated equal variances ($F = 2.64$, $p = 0.076$) so post hoc pair wise comparisons were conducted using the Tukey HSD test. Results of Tukey HSD indicated that test scores for the simple feedback condition did not differ significantly from test scores with positive feedback condition ($p = .68$) and from test scores with negative feedback condition ($p = .89$). Test scores from the positive feedback condition also did not differ significantly from the test scores from the negative feedback condition ($p = .99$). A means plot below represents the marginal means of the test scores for the Analysis DLO.

Figure 19: Marginal Means for the Analysis DLO



Finding – Independent Variable 2: Difference in learning with differential feedback based on participants' computer experience

The results of the post tests for each of the digital learning objects were next analyzed based on differential feedback and computer experience (Independent variable two) using factorial randomized-groups, fixed effects design and Pearson correlation where appropriate.

The first independent variable for all of the analyses was levels of feedback and the second independent variable was computer experience. Computer experience was measured five ways using the pre-study survey (appendix 3). The first measure of computer experience determined how many online courses the participant had previously completed. The second measure of computer experience determined the frequency the participant played video games both in the past and in the present. The third measure of computer experience determined the frequency the participant used social media in the past and the present. The fourth measure of computer experience, which could be better described as computer attitude, was determined using the Computer Attitude Scale developed by Nickell and Pinto (1986). The last measure of computer experience was determined from the participants' self rating of their level of computer experience on a likert scale. Post hoc pair wise comparisons were conducted where appropriate.

Levels of Feedback and Number of Online Courses.

The first measure of computer experience was a question on the pre-study survey that determined that the number of online course the participant completed. 63 participants had not completed an online course, 18 participants had completed one online course, six participants had completed 2 online courses, one participant had completed three online courses, seven participants had completed four online courses, and four participants had completed five online courses. Sample sizes were only large enough to complete analyses for participants who had not completed an online course or had completed one online course. 3x2 ANOVA's were conducted for each of the three digital learning objects. Analyses used feedback and number of online courses (0, 1) as between-subjects factors, and post hoc analyses were conducted as appropriate.

The results for the Application DLO revealed no significant main effect for levels of feedback, $F(2,68) = .81$, $p =.45$, $\eta_p^2 = .023$, and no main effect for number of online courses $F(1,68) = .54$, $p = .45$, $\eta_p^2 = .008$. Additionally, the interaction between levels of feedback and number of online courses was not found to be significant $F(2,68) = 2.86$, $p = .064$, $\eta_p^2 = .078$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

The results for the Evaluation DLO also revealed no significant main effect for levels of feedback, $F(2,53) = .63$, $p =.54$, $\eta_p^2 = .023$, and no main effect for number of online courses $F(1,53) = 1.49$, $p = .23$, $\eta_p^2 = .027$. Additionally, the interaction between levels of feedback and number of online courses was not found to be significant $F(2,53) = .39$, $p = .68$, $\eta_p^2 = .015$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

As with the results for the Application DLO and the Evaluation DLO, the results for the Analysis DLO also revealed no significant main effect for levels of feedback, $F(2,53) = .39$, $p =.68$, $\eta_p^2 = .015$, and a no main effect for number of online courses $F(1,53) = .004$, $p = .95$, $\eta_p^2 < .001$. Additionally, the interaction between levels of feedback and number of online courses was not found to be significant $F(2,53) = 1.91$, $p = .16$, $\eta_p^2 = .067$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

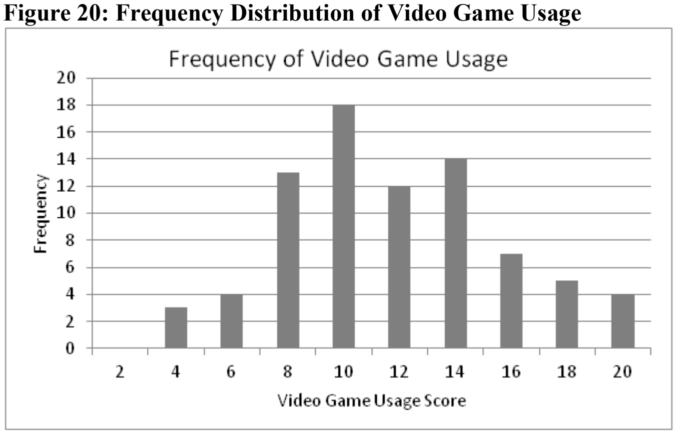
Levels of Feedback and Video Game Usage

The second measure of computer experience was determined from a question on the pre-study survey that asked the participant to indicate their frequency of video game usage. The question asked the participants to indicate how much time they spent playing video games, on average, per week, during the following:

	Not at all	1 – 3 hours	4 – 6 hours	7 -10 hours	>10 hours
In Recent Weeks	O	O	O	O	O
While in High School	O	O	O	O	O
While in Junior High	O	O	O	O	O
While in Elementary	O	O	O	O	O

A total video games usage score was calculated for each participant by assigning values for each category. The category "not at all" was assigned a score of one and ">10 hours" was assigned a score of five in order to quantify the results in order to determine comparative scores. The other three categories were assigned scores of two through four respectively. Potential video game usage scores could range from four through twenty and a chart of the frequency distribution of the scores are shown in Figure 20: Frequency Distribution of Video Game Usage. The results for the video game usage and the post-tests were analyzed to determine the level of correlation between the video game usage score and the post-tests scores. Additionally, 3x4 ANOVA's were conducted for each of the three digital learning objects. Analyses used feedback and video game usage scores as between-subjects factors, and post hoc analyses were conducted as appropriate.

Figure 20: Frequency Distribution of Video Game Usage



Correlations were completed for all of the participants for each digital learning object. Additionally, the data for each digital learning object was sorted by feedback type and correlations were completed to determine if there was any difference in the correlations between the video game usage scores and the post-test scores based on levels of feedback. Figure 21 below shows the correlation between the video game usage scores and post-test scores. Significant correlations ($p < .05$) were only found for the negative feedback condition for the Application DLO, Pearson's $r(24) = .48$, $p = .048$ and for the positive feedback condition for the Evaluation DLO, Pearson's r(22) = .505, $p = .016$. The correlations were small as indicated in the scatter plots for both as shown in Figure 222 and Figure 233 below.

Figure 21: Video Game Usage Correlations

		Application DLO	*Evaluation DLO*	*Analysis DLO*
All	Pearson Correlation	0.124	0.181	0.171
	Sig. 2-tailed	0.291	0.159	0.179
	N	74	62	63
simple feedback	Pearson Correlation	-0.05	0.006	0.344
	Sig. 2-tailed	0.82	0.978	0.138
	N	23	22	20
positive feedback	Pearson Correlation	0.127	0.505	0.002
	Sig. 2-tailed	0.527	0.016	0.992
	N	27	22	22
negative feedback	Pearson Correlation	0.408	0.031	0.298
	Sig. 2-tailed	0.048	0.903	0.189
	N	24	18	21

Figure 22: Application DLO (negative feedback condition) Scatter plot – Video Game Usage

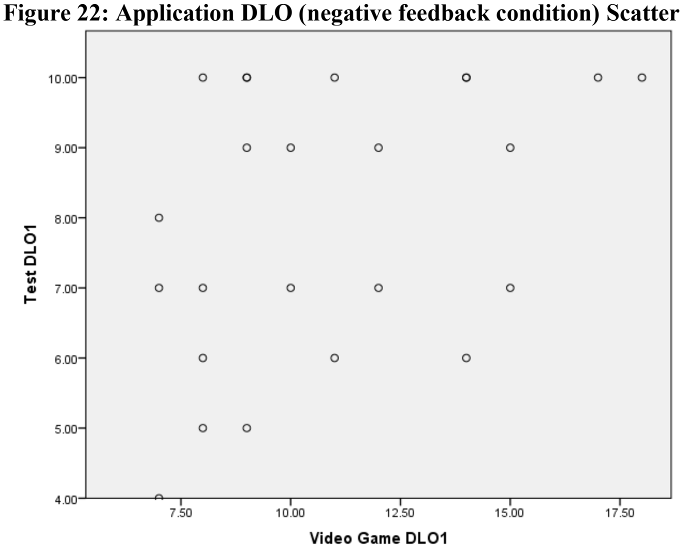
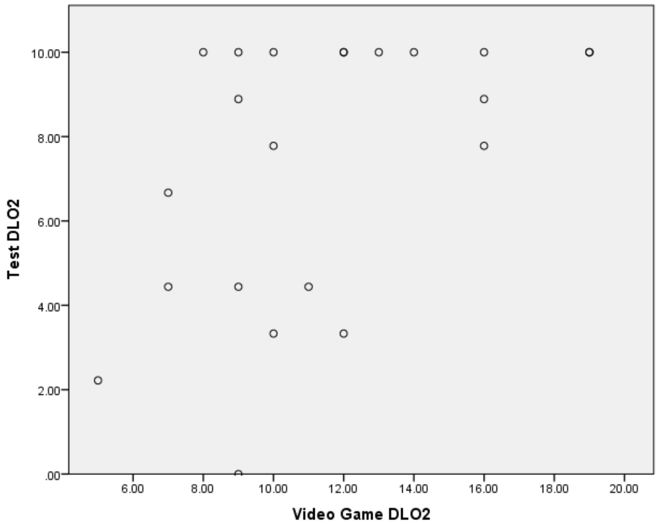


Figure 23: Evaluation DLO (positive feedback condition) Scatter plot – Video Game Usage



The results of the ANOVA for the Application DLO revealed no significant main effect for levels of feedback, F(2,62) = .11, p =.90, η_p^2= .004, and no main effect for video game usage F(3,62) = 1.19, p = .32, η_p^2= .054. Additionally, the interaction between levels of feedback and video game usage was not found to be significant F(6,62) = .59, p = .74, η_p^2= .054. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

The results of the ANOVA for the Evaluation DLO also revealed no significant main effect for levels of feedback, F(2,50) = .65, p =.52, η_p^2= .025, and no main effect for video game usage F(3,50) = .99, p = .40, η_p^2= .056. Additionally, the interaction between levels of feedback and video game usage was not found to be significant F(6,50) = 1.08, p = .39, η_p^2= .12. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

The results of the ANOVA for the Analysis DLO also revealed no significant main effect for levels of feedback, F(2,51) = .44, p =.65, ηp^2 = .017, and no main effect for video game usage F(3,51) = 1.36, p = .27, ηp^2 = .074. Additionally, the interaction between levels of feedback and video game usage was not found to be significant F(6,51) = .83, p = .56, ηp^2 =

.089. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

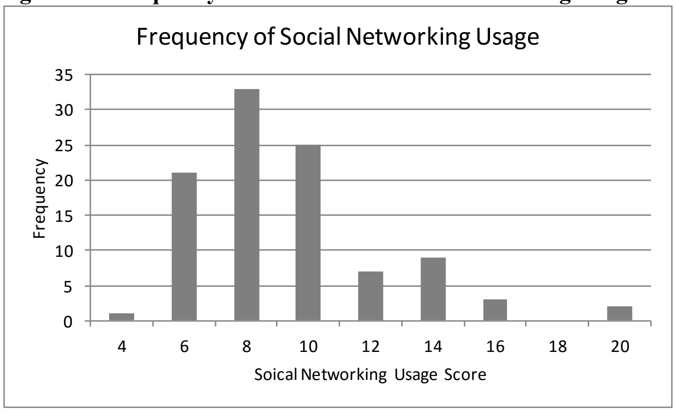
Levels of Feedback and Social Networking

The third measure of computer experience was determined from a question on the pre-study survey that asked the participant to indicate their frequency of social networking usage recently and historically. The question asked the participants to indicate how much time they spent using social networking (ie, Facebook, Twitter, Instagram, LinkedIn, Pinterest), on average, per week, during the following:

	Not at all	1 – 3 hours	4 – 6 hours	7 -10 hours	>10 hours
In Recent Weeks	O	O	O	O	O
While in High School	O	O	O	O	O
While in Junior High	O	O	O	O	O
While in Elementary	O	O	O	O	O

As with video game usage, social networking usage score was calculated for each participant by assigning the same scores for each category. The category "not at all" was assigned a score of one and ">10 hours" was assigned a score of five in order to determine an overall video usage score. The other three categories were assigned scores of two through four respectively. Potential social networking usage scores could range from four through twenty and a chart of the frequency distribution of the scores are shown in Figure 2424. The results for the social networking usage and the post-tests were analyzed to determine the level of correlation between the social networking usage score and the post-tests scores. Additionally, 3x4 ANOVA's were conducted for each of the three digital learning objects. Analyses used feedback and social networking usage scores (4-7, 8-11, 12-15, 16-20) as between-subjects factors, and post hoc analyses were conducted as appropriate.

Figure 24: Frequency Distribution of Social Networking Usage



Correlations were completed for all of the participants for each digital learning object. Additionally, the data for each digital learning object was sorted by feedback type and correlations were completed to determine if there was any difference in the correlations between the social networking usage scores and the post-test scores based on levels of feedback. Figure 2525 below shows the correlation between the social networking usage scores and post-test scores. No significant correlations ($p < .05$) were found between social networking usage scores and post-test scores.

Figure 25: Social Media Usage Correlations

		Application DLO	*Evaluation DLO*	*Analysis DLO*
All	Pearson Correlation	0.037	-0.051	-0.068
	Sig. 2-tailed	0.723	0.655	0.551
	N	94	78	78
simple feedback	Pearson Correlation	0.04	-0.215	-0.042
	Sig. 2-tailed	0.827	0.271	0.841
	N	32	28	25
positive feedback	Pearson Correlation	-0.066	0.166	-0.108
	Sig. 2-tailed	0.723	0.39	0.593
	N	31	29	27
negative feedback	Pearson Correlation	0.287	-0.034	0.007
	Sig. 2-tailed	117	0.883	0.972
	N	31	21	26

The results of the ANOVA for Application DLO revealed no significant main effect for levels of feedback, $F(2,83) = .98$, $p = .38$, $\eta_p^2 = .023$, and no main effect for social networking usage $F(3,83) = .83$, $p = .48$, $\eta_p^2 = .029$. Additionally, the interaction between levels of feedback and social networking usage was not found to be significant $F(5,83) = .68$, $p = .64$, $\eta_p^2 = .039$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

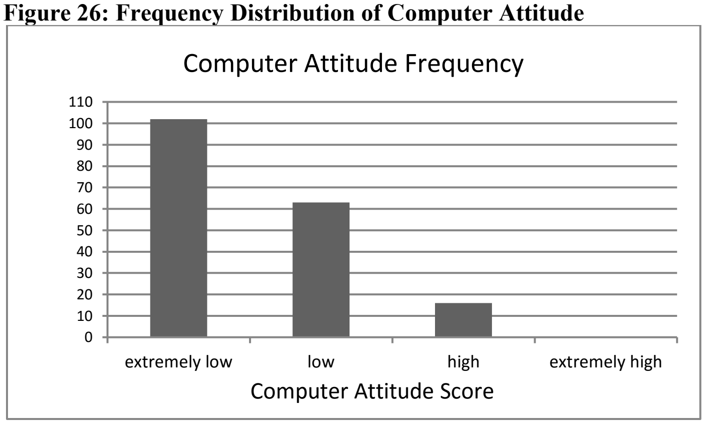
The results of the ANOVA for the Evaluation DLO revealed no significant main effect for levels of feedback, $F(2,68) = .72$, $p = .49$, $\eta_p^2 = .021$, and no main effect for social networking usage $F(3,68) = .50$, $p = .69$, $\eta_p^2 = .022$. Additionally, the interaction between levels of feedback and social networking usage was not found to be significant $F(4,68) = .78$, $p = .54$, $\eta_p^2 = .044$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

The results of the ANOVA for the Analysis DLO also revealed no significant main effect for levels of feedback, $F(2,68) = .29$, $p = .75$, $\eta p^2 = .008$, and no main effect for social networking usage $F(3,68) = .29$, $p = .83$, $\eta p^2 = .013$. Additionally, the interaction between levels of feedback and social networking usage was not found to be significant $F(4,68) = .22$, $p = .93$, $\eta p^2 = .013$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

Levels of Feedback and Computer Attitude

The next measure of computer experience was determined from a series of questions on the pre-study survey which were from The Computer Attitude Scale developed by Nickell & Pinto (1986). The computer attitude scale is a series of 20 questions measured on a likert scale that determines the participant's computer attitude score between 20 and 100 with a score of 20 representing an extremely low attitude towards computers and a score of 100 representing an extremely high attitude towards computers. The computer attitude scores were assigned to four categories. The first category, "extremely low attitude" was assigned for scores ranging from 20-39, the second category, "low attitude" was assigned for scores ranging from 40-59, the third category, "high attitude" was assigned for scores ranging from 60-79, and the last category, " extremely high attitude" was assigned for scores ranging from 80-100. There were 102 responses for computer attitude with 23 participant's scores in the "extremely low attitude" category, 63 participants in the low attitude category, 16 in the high category, and no scores in the "extremely high attitude" category. The frequency distribution for overall computer scores on computer attitude is shown in Figure 26: Frequency Distribution of Computer Attitude below.

Figure 26: Frequency Distribution of Computer Attitude



A 3x2 ANOVA was conducted for the data from each of the three digital learning objects with the independent variables of feedback (no feedback, positive feedback, negative feedback) and computer attitude (extremely low attitude, low attitude, high attitude) as between-subjects factors.

The results for the Application DLO revealed no significant main effect for levels of feedback, $F(2,86) = .42$, $p = .66$, $\eta_p^2 = .010$, and computer attitude, $F(2,86) = 1.26$, $p = .66$, $\eta_p^2 = .010$. Additionally, the interaction between levels of feedback and computer attitude was not found to be significant F(4,86) = .71, p = .59, η_p^2= .032. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

The results for the Evaluation DLO revealed a significant main effect for levels of feedback, F(2,69) = 3.27, p =.044, η_p^2= 0.087 and no significant main effect for computer attitude, F(2,69) = .46, p = .63, η_p^2= .013. Additionally, the interaction between levels of feedback and computer attitude showed a suggestive significant main effect F(4,69) = 2.45, p = .055, η_p^2= .12. Since a main effect was found for levels of feedback, post hoc analyses were conducted. Separate one way ANOVAs were conducted separately for the levels of feedback for three levels of computer attitude (extremely low attitude, low attitude, high attitude). Extremely high levels of computer attitude were omitted in the analysis since there were no participants with scores in the extremely high level category.

The first post hoc, one way ANOVA for the Evaluation DLO was conducted on the test scores for only participants who had an extremely low attitude towards computers. The ANOVA used feedback as the independent variable and indicated that there was a significant main effect for feedback F(2,14) = 4.43, p =.032, η_p^2= 0.39. Levene's test of homogeneity of variance indicated equal variances (F = .95, p = .41) so post hoc pair wise comparisons were conducted using the Tukey HSD test. Results of the Tukey HSD test indicated that test scores for the simple feedback condition did differ significantly from test scores with positive feedback condition (p = .033), and there was a suggestive effect from test scores with negative feedback condition (p = .067). Additionally, test scores from the positive feedback condition did not differ significantly from the test scores from the negative feedback condition (p = .860). The mean score for participants in the simple feedback group was 3.80, the mean score for participants in the positive feedback group was 8.50 and the mean score for the negative feedback group was 7.80. While the results were found to be significant, the sample size for this group was very low with N=15.

The second post hoc one way ANOVA for the Evaluation DLO was conducted on the test scores for only participants who had low computer attitude. The ANOVA used the feedback independent variable and indicated that there was no significant main effect for feedback $F(2,844) = .72$, $p = .49$, $\eta_p^2 = 0.032$. Consequently, post hoc tests comparisons were not conducted for the test scores from the participants who had low computer attitude.

The third post hoc one way ANOVA for the Evaluation DLO could not be conducted on the test scores for only participants who had high computer attitude because the sample size was too small with N=14 and only one participant was in the negative feedback condition.

The results for the Analysis DLO revealed no significant main effect for levels of feedback, $F(2,68) = 1.36$, $p = .26$, $\eta_p^2 = 0.038$, and for computer attitude, $F(2,68) = 2.23$, $p = .12$, $\eta_p^2 = .061$. Additionally, the interaction between levels of feedback and computer attitude was not found to be significant $F(4,68) = 1.68$, $p = .17$, $\eta_p^2 = .090$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

Levels of Feedback and Computer Experience

The last measure of computer experience was determined from a question on the pre-study survey that asked the participant to self rate their level of computer experience as no experience, little experience, average experience or high experience. Two participants rated themselves as having little experience, 59 participants rated themselves as having average experience, and 39 participants rated themselves as having high experience. No participants rated themselves as having no experience. Given that no participants rated themselves with no experience and only two participants rated themselves as having little experience, analyses were conducted for only participants with average or high experience. 3x2 ANOVAs were conducted for each of the three digital learning. Analyses used feedback and computer experience (average experience, high experience) as between-subjects factors, and post hoc analyses were conducted as appropriate.

The results of the ANOVA for the Application DLO revealed no significant main effect for levels of feedback, $F(2,85) = .31$, $p =.74$, $\eta_p^2 = .007$, and no main effect for computer experience $F(1,85) = .76$, $p = .39$, $\eta_p^2 = .009$. Additionally, the interaction between levels of feedback and computer experience was not found to be significant $F(2,85) = .23$, $p = .80$, $\eta_p^2 = .005$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

The results of the ANOVA for the Evaluation DLO also revealed no significant main effect for levels of feedback, $F(2,68) = .17$, $p =.84$, $\eta_p^2 = .005$, and no main effect for computer experience $F(1,68) = .94$, $p = .34$, $\eta_p^2 = .014$. Additionally, the interaction between levels of feedback and computer experience was not found to be significant $F(2,68) = .64$, $p = .53$, $\eta_p^2 = .019$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

The results of the ANOVA for the Analysis DLO also revealed no significant main effect for levels of feedback, $F(2,69) = .53$, $p =.59$, $\eta p^2 = .015$, and no main effect for computer experience $F(1,69) = .37$, $p = .55$, $\eta p^2 = .005$. Additionally, the interaction between levels of feedback and computer experience was not found to be significant $F(2,69) = .85$, $p = .43$, $\eta p^2 = .024$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

Other Analyses

In addition to measures of computer experience, additional data was collected throughout the course of the study. Two additional sets of data were collected using the pre-study survey. These were gender and age, and the post tests for each of the digital learning objects were analyzed based on differential feedback and these two factors. While age and gender were not directly identified as variables in the study, age and gender were identified as possible considerations in the literature in terms of differences in learning and computer attitude when using digital learning objects. Kay and Knaack (2008b) noted that males tended to have much more positive attitudes and higher ability in respect to computer use, and age is a significant factor in both attitude and performance in regards to digital learning objects. They also found that post-secondary students performed significantly better and had a more positive attitude than secondary students.

The data for gender was analyzed using an ANOVA and the data for age was analyzed using a Pearson correlation. Additionally, while the participants were completing the digital learning objects, the time on task was recorded and an analysis completed below to determine if there was a correlation between time on task and their score on the post test. There were two separate measures for time on task. The first measured the time the participant took to complete the lesson portion of the digital learning object and the second measured the time the participant took to complete the guided practice portion of the digital learning objects. The data was analyzed separately for each digital learning object. Post hoc pair wise comparisons were conducted where appropriate.

Levels of Feedback and Gender

Of the participants who completed the pre-study survey, 77 participants were male and 26 were female. 3x2 ANOVAs were conducted for each of the three digital learning objects as well as for the combined data from all of the learning objects. Analyses used feedback and gender (male, female) as between-subjects factors, and post hoc analyses were conducted as appropriate.

The results of the ANOVA for the Application DLO revealed no significant main effect for levels of feedback, $F(2,90) = .94$, $p = .34$, $\eta_p^2 = .020$, and no main effect for gender $F(1,90) = 1.88$, $p = .17$, $\eta_p^2 = .020$. Additionally, the interaction between levels of feedback and gender was not found to be significant $F(2,90) = .30$, $p = .74$, $\eta_p^2 = .007$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

The results of the ANOVA for the Evaluation DLO also revealed no significant main effect for levels of feedback, $F(2,73) = .58$, $p = .56$, $\eta_p^2 = .016$, and no main effect for gender $F(1,73) = .78$, $p = .38$, $\eta_p^2 = .011$. Additionally, the interaction between levels of feedback and gender was not found to be significant $F(2,73) = .12$, $p = .89$, $\eta_p^2 = .003$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

The results of the ANOVA for the Analysis DLO also revealed no significant main effect for levels of feedback, $F(2,72) = 1.70$, $p = .19$, $\eta p^2 = .045$, and no main effect for gender $F(1,72) = .60$, $p = .44$, $\eta p^2 = .008$. Additionally, the interaction between levels of feedback and gender was not found to be significant F(2,72) = 1.33, p = .27, $\eta p^2 = .036$. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

Levels of Feedback and Age

Age was determined from the pre-study survey and an analysis was conducted using Pearson correlation to determine if there was a correlation between the age and the post-test scores. Correlations were completed for all of the participants for each digital learning object, and the data for each digital learning object was sorted by feedback type. Correlations were completed to determine if there were any significant differences in the correlations between the participants' age and their post-test scores based on levels of feedback. Figure 27: Frequency Distribution of Age below shows the frequency distribution of the ages of the participants and Table 66 shows correlations between the participants' ages and their post-test scores. No significant correlations ($p < .05$) were found between age and post-tests scores.

Figure 27: Frequency Distribution of Age

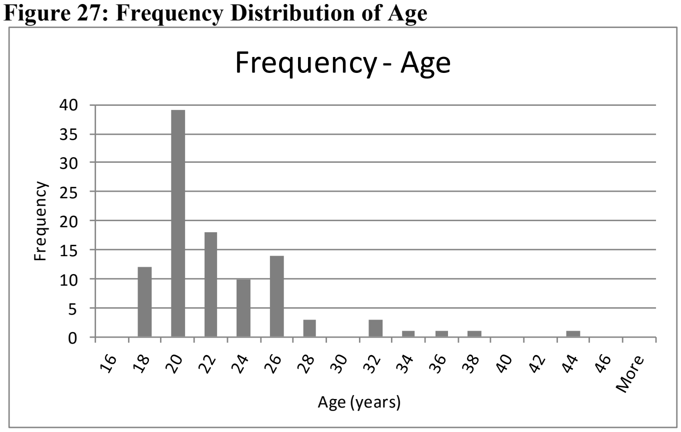


Table 6: Age Correlations

		Application DLO	Evaluation DLO	Analysis DLO
All feedback combined	Pearson Correlation	-.089	.076	.123
	Sig. 2-tailed	0.386	0.504	.283
	N	96	79	78
simple feedback	Pearson Correlation	-.012	-0.039	.111
	Sig. 2-tailed	0.949	0.844	0.597
	N	32	28	25
positive feedback	Pearson Correlation	-0.191	0.109	.048
	Sig. 2-tailed	0.295	0.575	.813
	N	32	29	27
negative feedback	Pearson Correlation	-.046	.055	.107
	Sig. 2-tailed	.804	0.808	.612
	N	32	22	26

Levels of Feedback and Time on Task

The digital learning objects the participants completed were organized into two parts. The first part was a lesson that participants completed where the participants were not asked to complete any questions during the lesson portion of the digital learning objects and simple feedback was given. The second section of the digital learning objects was a guided practice part where the participants were guided step by step through a problem and asked multiple choice questions during each step of the problem. Feedback for each answer was either, simple feedback, positive feedback or negative feedback depending on which treatment condition the participant was placed in. Both the lesson and the guided practice parts were timed to determine the total time on task in seconds. Pearson correlations were completed for the data for both the guided practice part and the lesson part to determine if there were significant correlations between time on task and post-test scores.

Correlations were completed for the time on task for both the lesson part and the guided practice part of the digital learning objects. The data for each digital learning object was sorted by feedback type, and correlations were completed using the participants' post-test scores and both the time on task on the lesson part and the time on task on the guided practice part of the digital learning objects. Table 7 shows correlations between the participants' time on task for the lesson part and their post-test scores, and Table 8shows correlations between the participants' time on task for the guided practice part and their post-test scores. Significant correlations ($p <$ .05) for the lesson time and the guided practice time compared to the post-test scores were only found for the results of the Evaluation DLO. The lesson time for Evaluation DLO had significant correlation with the post-test scores for the simple feedback condition, Pearson's r (30) = .43, p = .019 and the negative feedback condition, Pearson's r (26) = .49, p = .011. The guided practice time for Evaluation DLO had significant correlation with the post-test scores for the simple feedback condition, Pearson's r(30) = .46, p = .011 and the positive feedback condition, Pearson's r (33) = -.32, p = .067.

Table 7: Lesson Time Correlations

		Application DLO	*Evaluation DLO*	*Analysis DLO*
All	Pearson Correlation	-0.175	0.149	0.05
	Sig. 2-tailed	0.065	0.164	0.635
	N	112	89	94
simple feedback	Pearson Correlation	-0.336	0.426	0.258
	Sig. 2-tailed	0.034	0.019	0.176
	N	40	30	29
positive feedback	Pearson Correlation	-0.128	-0.124	-0.052
	Sig. 2-tailed	0.463	0.491	0.762
	N	35	33	36
negative feedback	Pearson Correlation	0.091	0.491	0.058
	Sig. 2-tailed	0.593	0.011	0.766
	N	37	26	29

Table 8: Guided Practice Time Correlations

		Application DLO	*Evaluation DLO*	*Analysis DLO*
All	Pearson Correlation	-0.129	-0.045	0.006
	Sig. 2-tailed	0.174	0.674	0.955
	N	112	89	94
simple feedback	Pearson Correlation	-0.128	0.459	.171.
	Sig. 2-tailed	0.431	0.011	0.375
	N	40	30	29
positive feedback	Pearson Correlation	-0.195	-0.322	-0.153
	Sig. 2-tailed	0.262	0.067	0.373
	N	35	33	36
negative feedback	Pearson Correlation	-0.035	0.032	0.197
	Sig. 2-tailed	0.836	0.878	0.306
	N	37	26	29

Levels of Feedback and Guided Practice Time on Task

ANOVAs for each digital learning object were also conducted with the time on task for the guided practice part of the digital learning objects as the dependent variable and feedback (simple feedback, positive feedback, negative feedback) as the between subject-factor. The ANOVAs were used to determine if there was a significant effect of feedback on the time on task for the guided practice part of each digital learning object. Each of the ANOVAs was conducted separately for the results of each digital learning object.

The results of the ANOVAs indicated that there were no significant main effects for levels of feedback with guide practice time as the dependent variable for any of the digital learning objects as well as the combined data from all of the digital learning objects. The ANOVA results for each of the application, evaluation and analysis digital learning objects were $F(2,109) = .45$, $p = .64$, $\eta_p^2 = .008$, $F(2,86) = .94$, $p = .40$, $\eta_p^2 = .021$, $F(2,91) = 1.41$, $p = .25$, $\eta_p^2 = .030$ respectively. Since no main effect was found for levels of feedback, post hoc analyses were not conducted.

Participant comments

Participants were asked to provide additional open-ended comments about the digital learning objects at the end of the post-study survey (appendix 5). While the comments were not designed to address a particular research question or to be used for explanatory purposes as described by Creswell and Plano Clark (2011), it did offer some insight into the experience the participants had using the digital learning objects and are summarized and discussed below in relation to the research questions. Additionally, Kay and Knaack (2008a) have shown student attitude about the use of digital learning objects was dependent on the education level of the student with a greater percentage of students in post-secondary reporting a positive attitude towards digital learning objects as compared to secondary students. Kay and Knaack (2008a) looked at a number of studies that investigated student attitude towards learning objects with post-secondary students and found that eight studies reported positive student attitude, one study reported neutral attitude and one study reported a negative attitude. Post-secondary students typically gave positive comments about characteristics such as animations, self-assessment, attractiveness, control over learning, ease of use, feedback, scaffolding or support, interactivity, navigation and self efficacy. Consequently, collecting open-ended comments about student attitude was seen to be of some value as student attitude about the use of digital learning objects was related to the independent variables of levels of feedback, and previous knowledge.

The comments were analyzed by coding and grouping into themes. Three major themes emerged from the analysis which were positive comments, suggestions for improvement and negative comments. The first theme represented positive comments totalling 59 which is consistent with what Kay (2014) reported about student attitude and using digital learning objects. Other themes were suggestions for improvements totalling 5 and negative comments which totalled to 3. Each of the themes were then sub themed with 9 sub themes emerging for the positive codes with two additional codes that did not fit into one of the sub themes. There weren't sufficient numbers of codes that were suggestions for improvements or negative comments to create sub themes.

Table 9 below represents the themes, sub themes and count of each.

Table 9: Themed Participant Comments

Theme	Sub Themes/codes	Count
Positive comments	Good experience	16
	DLOs are a good supplement to classroom teaching	12
	DLOs are a good learning tool	7
	The DLOs are easy to understand	7
	The DLOs were helpful	5
	Having steps was good	4
	Please implement ASAP	2
	Liked that they were self paced	2
	Had good visuals	2
	Superior to MyMath Lab	1
	Liked that it started at a beginner level	1
Suggestions for Improvement	Needs more feedback	1
	Needs more questions at the end	1
	Would like more examples	1
	Would like voice over	1
	Would like more interaction	1
Negative comments	Animations were distracting	1
	Eyes hurt working on the DLOs for so long	1
	Too many words to read	1

Validity and Reliability

Internal Validity

The design of the study protected against threats to internal validity in a number of ways. One of the ways the design of the study protected against threats to internal validity was to measure computer experience through multiple measures. This allowed for multiple analyses on the same independent variable. Additionally, computer experience was not only determined by multiple measures, but computer experience was also determined through a number of measures that determined computer experience and a single measure that determined computer attitude. Another way that the design of the study protected against threats to internal validity was by having the participants complete multiple digital learning objects on topics that were unrelated and none of the concepts of any of the topics presented prerequisite knowledge for any of the others.

External Validity

The design of the digital learning objects, the demographics of the participants, and the topics chosen for the digital learning objects had an impact on the external validity of the results of the study. The design of the learning objects impacted external validity in that the learning objects were designed to be completed in a linear fashion in which the participants followed a predetermined path of a lesson and guided practice. While this design helps to increase the reliability of the results by ensuring all participants complete all parts of the digital learning objects, to some degree it limits the external validity of the results as it may be difficult to generalize the results to other designs. Additionally, the question types of the digital learning objects were multiple choice questions. Multiple choice questions helped create consistency in questioning and how feedback was given, thus increasing reliability, but potentially they decreased the ability to generalize the results to digital learning objects with other question types.

Another threat to external validity in the study was the demographics of the participants. All of the participants were post-secondary students enrolled in a Calculus class in the first year of an Engineering Technology program. Other groups in terms of education program and age may respond differently to different levels of embedded feedback.

The topics chosen for the study may have also posed a threat to external validity in terms of the topic, the complexity of the topic, and type of problems. The topics selected were for the digital learning objects were all topics that typically make up an introductory post-secondary calculus course, which could impact whether the results could be generalized to other mathematics topics or non-math topics. Also, the complexity and the type of problems may have an impact on the external validity of the results. Two of the topics were more complex than the other in that the questions were word problems and involved multiple steps to learn and required higher level thinking skills. The topic of the Evaluation DLO was not as complex and the questions asked were not word problems but were instead problems that were solved algebraically.

Reliability

There were a number of issues in regards to the reliability of the data which mostly centered on the collection of the data. The first issue was that not every participant completed the pre-study questionnaire. While the pre-study questionnaire was completely voluntary, there is a risk that those participants who chose not to complete the pre-study questionnaire may have been a homogeneous group and consequently impacted the random distribution of the participants. The second issue was that that not all of the participants were able to complete every digital learning object. The data collection occurred during the participants' regularly scheduled calculus classes; however, for various reasons not all were able to attend. The instructors for the classes indicated that some participants did not attend some of the sessions because there was a scheduled midterm examination in another course that the participants were preparing for. This could have impacted the distribution of the student as there is a possibility that the participants studying for other classes could have been similar in their ability or experience which could have impacted the makeup of the sample. The third issue with reliability is that there were two occasions where technical difficulties disrupted some of the participants' ability to complete the digital learning objects during the scheduled class period. In both cases, the participants were encouraged to complete the digital learning objects at a later time and provisions were made to extend the time that the digital learning objects and post-test were available to the participants. The threat to the reliability by doing this is that the participants were not monitored when they completed the digital learning objects on their own. However, clear directions were provided on the Moodle page and by the course instructor to only rely on the learning from the digital learning objects to complete the post-tests. That last threat to reliability was that it was not possible to control whether the participants reviewed the concept presented in the digital learning objects prior to completing the digital learning objects. This could have impacted the analyses for prior knowledge as their results on the post-tests may not have been consistent with their reported prior knowledge in the pre-study survey.

Conclusion

This chapter analyzed the data from the various learning objects examining whether there was a significant effect on learning by embedding feedback into digital learning objects. Analyses were further completed by examining feedback in relation to various measures of computer attitude in addition to gender and age which have been shown to be related to computer attitude. Significant main effects were found for a number of analyses, most notably in relation to computer experience and feedback. These are further discussed in the following chapter.

CHAPTER FIVE – DISCUSSION

Van der Kleij, Feskens and Eggen (2015) identified a number of gaps in the literature in the area of the effect of feedback in online learning.They recommend that future research investigate the characteristics of the feedback as well as the task, the learning context and the characteristics of the learners. This study extends the research in feedback in online research identified by Van der Kleij, Feskens and Eggen (2015) by exploring levels of feedback as a characteristic of online learning in the learning context of digital learning objects. Characteristics of the learner were also explored in relation to levels of feedback.

The learning context selected for this study was digital learning objects. This is because as Kay (2012) observes, that " a comprehensive examination of factors that might influence the effectiveness of learning objects including student characteristics, design of learning objects, and teaching strategy has yet to be conducted" (p. 351). Additionally, Watson (2010) contends that there has been an emphasis on the technological aspects of digital learning objects such as reusability as well as the visual appearance of the digital learning objects, but there has been a lack of research into the pedagogical basis for designing digital learning objects. This is also supported by Chikh (2012) who adds that previous research has focussed on targeting learners as consumers of digital learning objects or targeted instructors and designers and focussed on the reusability of digital learning objects. By conducting this research specifically for digital learning objects and the effectiveness of feedback, this study focuses on feedback as a design element of digital learning objects that can increase learning rather than the technological aspects of digital learning objects. Additionally, by selecting learning objects, this study controls for learning context while extending the previous research on computer assisted instruction.

The type of feedback selected for this study was a type of elaborated feedback that Shute (2008) describes as response contingent feedback that describes why a correct response is correct and why an incorrect response is incorrect. For this study these were identified as positive and negative feedback respectively. Black and Wiliam (1998) and Davis and McGowen (2007) have shown that in an face to face context, positive and negative feedback have a positive influence on learning. This study also explores these findings in an online context using digital learning objects and seeks to extend what had previously explored in computer assisted instruction. The study was also designed to investigate the effect on achievement of a number of learner characteristics in relation to embedded feedback, specifically, computer experience. Additionally, age and gender were also examined as they have been shown to be related to computer attitude (Kay and Knaack, 2008a).

It is hoped that this study can be the catalyst for further empirical studies that investigate the factors that influence the design of digital learning objects. The findings and interpretations presented in this section will discuss the results of the study in relation to the research questions of study. This will be followed by recommendations as well as suggestions for further research.

Research Questions

1. Is there a difference in post-secondary students' learning based on the type of feedback they encounter while using an online digital learning object as a basis of instruction in an introductory calculus class? Types of feedback in this study will be feedback that addresses faulty interpretations and not a lack of understanding in the form of either positive or negative feedback as described by Black and Wiliam (1998) and Hattie and Timperley (2007).

2. Is there a difference in post-secondary students' learning based on the type of feedback they encounter using an online digital learning object in relation to learner characteristics of computer experience?

Findings and Interpretations based on the levels of feedback

The results of the 3x3 fixed effects ANOVA in this study did not find any statistically significant effects for levels of feedback and consequently there was no evidence to reject the first null hypothesis in the study which is: there is no difference in post-secondary students' learning based on the type of feedback in online digital learning objects. However, a close examination of the results from each of the three digital learning objects does show a consistent pattern with all three digital learning objects; learning for the digital learning objects with embedded feedback being greater than for the learning objects without feedback which suggests further investigation of the results and an examination of the methods used

When examining each of the digital learning objects, the structure of all three learning objects was identical in that the learning objects were all made up of two parts with a lesson section first which was followed by a guided practice section with the feedback embedded into the guided practice section of the digital learning object. The only identifiable difference between the three digital learning objects was that the Application DLO and Analysis DLO were both complex word problems whereas the Evaluation DLO was a simpler topic that identified the algebraic steps to solve a problem. This suggests that complexity may also be a factor that impacts the effect of the feedback in regards to learning when the feedback is embedded into the digital learning objects.

When examining the plots of all three digital learning objects and the plot of the combined data (Figure 28,
Figure 29, Figure 3030) it can be seen that a pattern is emerging where the simple feedback condition is consistently lower than the positive and negative feedback conditions whereas the positive and negative feedback conditions are consistently higher than simple feedback. It should be noted that the comparisons of the plots are comparing plots with different scales. Additionally, the plots are from the post-test results from three different digital learning objects and three different post-tests. Consequently comparisons are for examining trends only and not absolute differences in values. While there wasn't a significant difference shown for type of feedback for any of the digital learning objects, the pattern suggest that embedding feedback into digital learning objects could be a factor to further explore in the design in digital learning objects. In addition, the complexity of the topic should also be considered in the design of the digital learning objects when embedding feedback and that feedback may be more effective with less complex concepts. In this case, significant results were found in relation to computer attitude for the less complex, evaluation DLO which was only based on determining and evaluating algebraic step. Significant results were not found for the synthesis and application DLOs which were complex word problems. A possible explanation is that feedback with complex concepts requires more feedback and more frequent feedback which may become confusing. This supports Hatziapostolou and Paraskakis (2006) who contend that overly detailed and too much feedback can result in the feedback being too confusing and overwhelming to be useful. Regardless, the pattern shown in the plots suggest that feedback may be of some use regardless of the complexity. This also aligns with Hatziapostolou and Paraskakis (2010) who note that feedback

is important in all learning contexts. However, concepts that are less complex may also benefit more from embedded feedback.

Figure 28: Application DLO – Marginal Means for Feedback

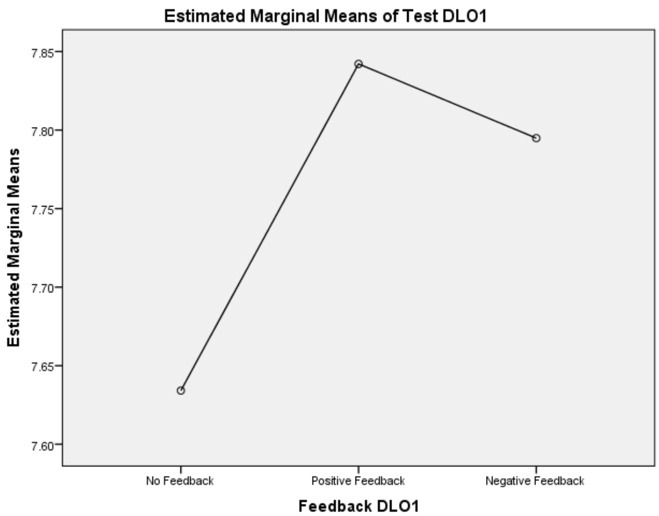


Figure 29: Evaluation DLO – Marginal Means for Feedback

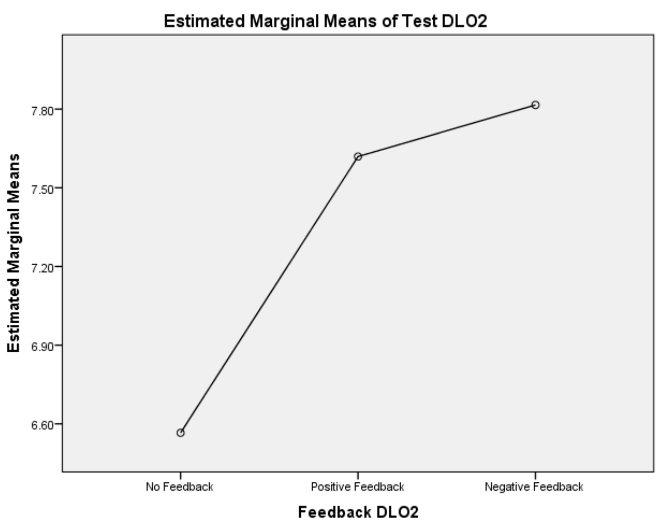
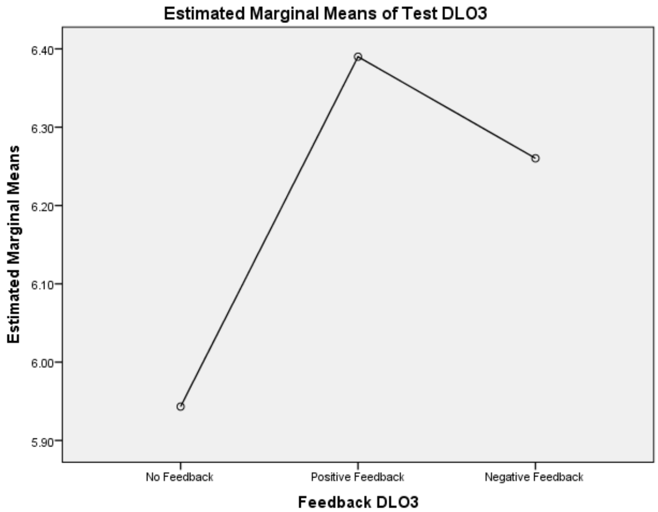


Figure 30: Analysis DLO – Marginal Means for Feedback



Difference in learning with differential levels of feedback based on participant's computer experience

The second set of analyses in this study was based on differential levels of feedback and computer experience. Computer experience was measured five ways using categorical data. The first four measures of computer experience were how many online courses the participant had previously completed, the frequency the participant played video games, the frequency the participant used social media, and a self rated level of computer experience measure on a likert scale. The last measure of computer experience could instead be defined as a measure of computer attitude and was determined using the Computer Attitude Scale developed by Nickell & Pinto (1986). The first four measures of computer experience did not reveal significant effects for levels of feedback and did not indicate and significant correlations. However, significant main effects were found with levels of feedback and computer attitude as between subject factors.

The separate analyses indicated that significant results were found in the Evaluation DLO with p = 0.044. These results from the ANOVA of the Evaluation DLO show that computer attitude was a significant factor in determining whether participants benefited from embedded feedback, but the results from the ANOVAs from the Application DLO and the Analysis DLO did not indicate that computer attitude was a significant factor. The Evaluation DLO was designed around a topic that is less complex than the topics for the Application DLO and the Analysis DLO. This suggests that complexity should be further examined as an additional factor in determining the effectiveness of embedding feedback in digital learning objects.

These results suggest that it may be appropriate to reject the second null hypothesis of: H_o: There is no difference in post-secondary students' learning in digital learning objects with differential levels of feedback based on the students' computer experience. However, it was found the there was a distinction between computer experience and computer attitude. Consequently, while there is evidence to reject the null hypothesis, it would only be in relation to computer attitude and not with computer experience. These results support Kay (2007) and Kay (2012) who suggested that students who are more comfortable with computers would likely benefit more from using digital learning objects as evidenced by the substantial amount of research on self-efficacy and computer related behaviours. However, as Kay (2007) noted, little research had been completed in regards to computer attitude and self efficacy in regards to the use of digital learning objects.

Difference in learning with differential feedback based on other factors

Further analyses were conducted based on levels of feedback and a number of other factors which include age, gender and time on task. An ANOVA for each DLO was used to analyze the results for gender and time on task and no significant main effect was found with feedback and gender or time on task as between subject factors. Additionally, within each DLO, there was no significant difference between the results between males and females. This is consistent with what has been reported in the literature in regards to learner characteristics in which there have been no observable significant differences between males and females or with regard to age (Kay & Knaack, 2008b; Van Zele, Vandaele, Botteldooren, & Lenaerts, 2003). Not surprisingly then, results of this study did not find that there was a significant difference between the results of males and females on the post-study test, and there was no significant main effect of feedback and gender as between subject factors. Age and time on task were also examined to see if there was a correlation between levels of feedback and age and levels of feedback and time on task. Only small correlations were found <0.5 and with no significant evidence to suggest that there was a correlation between the different levels of feedback and the factors of age and time on task.

Participant Comments

At the end of the study, all participants were provided the opportunity to provided open ended comments about the experience in using the digital learning objects. The participant comments from the post study survey were primarily positive comments and the sub themes show that the majority of the participants liked using the digital learning objects with some of the participants preferring to use the digital learning objects exclusively. While the comments were overwhelmingly positive and the participants indicated they liked using the digital learning objects, the participants were not able to comment on the efficacy of the embedded feedback as they were unaware that there were different groups in the study who had received different feedback conditions. One notable exception is a comment from a participant who was placed in the simple feedback condition and who commented that more feedback is needed.

All of the comments were consistent with what Kay and Knaack (2008a) and Kay (2014) found in regards to student attitude with using digital learning objects. They found that students typically gave positive comments about the characteristics of the digital learning objects such as animations, self-assessment, attractiveness, control over learning, ease of use, feedback, scaffolding or support, interactivity, navigation and self efficacy. Also, they found that negative comments were focussed on the navigation, the technology and the workload which is consistent with what the participants in this study reported. Another aspect of the design of the learning objects that the participants reported finding valuable in this study is that they were interactive, with explanations and visuals. This supports the study by Rieber, Tzeng and Tribble (2004) who indicated the computer based learning with embedded explanations and graphical representations were more effective than those without. Additionally, Lim et al. (2006) suggests that the level of interactivity found in digital learning objects was also an important design element to consider. A final factor to consider is that a number of the participants (n=12) did comment that the digital learning objects were good, but would work best as supplement to classroom instruction. This is supported by Nurmi and Jaakkola (2006) who found that learning of students using digital learning objects alone was not significantly different from students in a blended setting (digital learning objects and face to face) or to face to face only. They did find that the learning in a blended (digital learning objects and face to face) setting was significantly better than learning in a face to face setting only. This supports what many of the participants in this study suggested in that they believe the digital learning objects would be a good supplement to a face to face setting.

Recommendations

This study explored a number of gaps in the literature on the effect of feedback in online learning identified by Van der Kleij, Feskens and Eggen (2015). Type of feedback using digital learning objects as the learning context was explored as the primary focus of this study, where levels of feedback were simple feedback and elaborated feedback which was in the forms of positive or negative feedback as described by Black and Wiliam (1998) and Timberley (2007). Additionally, learner characteristics such as computer experience and attitude, gender and age were explored in relation to embedded feedback. In terms of the learning context of the study, as Kay (2007) and Kay (2014) noted, digital learning objects could potentially revolutionize online learning, but there is a lack of empirical studies focussing on the effective use and design of digital learning objects. This does not mean that there is not an interest in developing and using digital learning objects. Nurmi and Jaakkola (2006) noted that there continues to be enthusiasm towards using and designing digital learning objects. These statements are now eight and nine years old, and while the development of digital learning objects continues to grow with many publishers and developers creating learning objects as part of their online supports for textbooks on online courses, the state of research into the design of digital learning objects has changed little. As Kay (2013) observed recently, "a comprehensive examination of factors that might influence the effectiveness of learning objects including student characteristics, design of learning objects, and teaching strategy has yet to be conducted" (p. 351).

Results from this study suggest to the developer of digital learning objects that all users of digital learning objects could benefit to some degree from feedback in the learning objects as evidenced by the consistent pattern when examining the marginal means of the results. However, findings show that users with high computer attitude benefit significantly from embedded feedback while users with low or extremely low computer attitude do not. However, comments from participants were overwhelming positive regarding the use of digital learning objects with most rating the experience good, useful, and easy to use which suggests that the learning objects themselves offered an extra level of motivation to learn. Also, participants suggested that the digital learning objects would be best used in a blended learning environment with both face to face and online modes of delivery available. While participants in the study were not aware of the independent variable of feedback, the results would suggest that well designed learning objects with embedded feedback would be beneficial to users particularly in a blended learning setting and most useful for users with high computer attitude.

Researcher's Reflections

When planning and designing this study, the researcher borrowed from 25 years of experience of working in online education and teaching mathematics and science to both secondary and post-secondary students. Over the past 15 years the researcher has been designing and using digital learning objects as a part of his self-paced online courses and blended online courses. Anecdotal evidence suggested to the researcher that his students enjoyed using the digital learning objects and in some cases used them as their primary source for learning the topic. All of the digital learning objects that the researcher had designed in the past were similar to the lesson portion of the digital learning objects in this study; however, they did not include guided practice with embedded feedback. Whenever students had a difficult time with a specific concept presented in the digital learning objects, they would have to wait to contact the instructor for extra help. While this was sufficient in a blended learning setting where a student has regularly planned opportunities to interact with the instructor, the self-paced setting often provided less opportunity for the students to meet or discuss the concepts with the instructor, and any discussions were typically delayed. This suggested to the researcher that embedding feedback into digital learning objects that was similar to the feedback that the instructor would provide could be beneficial which ultimately helped to frame the problem and purpose of the study.

While the researcher had a keen interest in the results of the study in terms of the effect of embedded feedback, the opportunity allowed for exploring various other factors that could influence the effect of embedded feedback. The literature review also helped make evident that not only was elaborated feedback, response contingent feedback a factor to consider in designing digital learning objects, but that there were other factors to consider in relation to feedback for which few empirical studies had been completed. This study fully explored a factor in the effective design of digital learning objects using a controlled experiment and was the largest found in terms of participants in relation to digital learning objects. In order to complete this study, the researcher had to create three separate learning objects for each of three concepts and then ensure that the objects were made available to the participants as part of their normal activities in their classrooms while ensuring the timing of the delivery of the learning objects occurred just before the face to face delivery of the topic. This necessitated that the researcher explore and learn a delivery mechanism that was online and could deliver the correct learning object to the appropriate randomly selected group without the participants being aware that there were three treatment conditions. Also, the delivery of the learning objects had to be in a platform that the participants were familiar with and was easy to use and set up so it was intuitive for the participants to use. In consultation with a Moodle expert, the researcher was able to employ Moodle as the delivery platform to meet the requirements for delivery and to provide the testing capabilities necessary to conduct the study. As the researcher planned the study, questions remained about how to best present the learning objects to the participants. The researcher found that Moodle was not only appropriate, but has now demonstrated the functionality that was used for this study to other researchers who have similar methodological needs.

Suggestions for Further Research

In analyzing the data, a number of topics for further research emerged. One of these potential topics is exploring how the complexity of the concepts in the digital learning object may interact with the effectiveness of the embedded feedback in digital learning objects. The results of the study indicated that the complexity of the digital learning object content may have a played a role in the overall effectiveness of the digital learning objects. The topics presented in the digital learning objects in this study were word problems which represented analysis, application and evaluation as cognitive functions which typically are more complex and require higher level thinking skills as described by Bloom, Engelhart, Furst, Hill, and Krathwohl (1956). Potential research topics would include exploring the appropriate level of complexity or amount of information covered by the digital learning objects.

Summary and Conclusions

This quantitative study explored the effect of differentiating levels of feedback (simple, positive and negative) as a type of elaborated feedback using digital learning object as the learning context. A research hypothesis guided the study to explore whether computer experience influenced the effectiveness of embedded feedback in digital learning objects. The literature suggested that feedback is a significant factor in learning in a face to face setting and in online setting. This implied that feedback may also be a significant factor in the design of digital learning objects. This study with 141 participants randomly selected from post-secondary engineering first calculus classes found that feedback is a significant factor for learning for participants with high computer experience. Comments from participants suggested that the digital learning objects were useful as a learning tool both on their own or as a supplement to learning in a face to face setting.

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APPENDIX 1

Course Instructor: INFORMATION LETTER and CONSENT FORM

Study Title: Exploring Digital Learning Objects

Background

- You are being asked to participate in this study because you are the instructor of a Post-Secondary Calculus course which comprises the sample identified for this study.
- The results of this study will be used in support of the researcher's dissertation for completion of a PhD in Educational Psychology.

Purpose

- The purpose of this research study is to investigate the design of digital learning objects. Digital learning objects are computer based learning tools that are designed to teach or support the learning of a specific concept. Digital learning objects can range from digital images, videos, simulations to interactive computer programs designed to teach a specific concept. In this study, the digital learning objects being investigated are interactive computer programs.
- Research Questions:
    1. Is there a difference in students' learning based on the design of an online digital learning object as a basis of instruction in an introductory calculus class?
    2. Is there a difference in students' learning based on the design on an online digital learning object in relation to learner characteristic of the students' comfort level in using a computer?

Study Procedures

- This study will involve five modules that will be accessed through a Moodle course which is the Learning Management System (LMS) that all students at the Northern Alberta Institute of Technology (NAIT) use for the courses. Each module in Moodle will represent one part of the study.
    - The first module will be an online survey that will ask some questions on basic demographic information such as age and gender. The survey will also include a set of questions on your students' experience using a computer.
    - The second, third and fourth modules will all be modules that will contain the digital learning objects that will be used in the study. Each digital learning object will contain three parts. The first part will be a lesson on a specific concept in calculus. The second part will be guided practice where your students will answer questions on the concept presented in the lesson. The third part of the digital learning object will be a short quiz on the concept presented in the digital learning object.

  - The fifth module in the study will be a short post-study survey designed to gather feedback from your students on their thoughts and experiences while using the digital learning objects.

- Data to be collected.
  - Demographic data collected in the first module
    - Gender, age, highest level of math course taken, time since last math course taken, has the student completed a calculus course
    - A questionnaire which will include questions on a students' prior experience with using a computer and online learning.
  - Post-study survey. After your students have completed all of the digital learning objects they will be asked to complete a survey on their thoughts and experiences while using the digital learning objects.
  - Test scores will be collected from the quizzes taken after completing each of the three digital learning objects. All test scores from the quizzes will be collected during three 1 hour classroom periods. These one hour classroom periods will be part of the regularly scheduled activities of the class, and as such all students in your class will be expected to complete the digital learning activities. However, data for the study will only be collected from your students who have agreed to participate in the study. Students who have not agreed to participate in the study will access the digital learning objects through a guest Moodle account and will not be required to complete the pre and post study surveys.
  - There will be no extra time commitment for your students other than the time needed to complete the pre and post study surveys which will take approximately 10 minutes each to complete.

Benefits

- We hope that the information we get from doing this study will help us better understand how to better design digital learning objects to increase learning.
- All students in your class will be expected to complete the digital learning objects as part of the regularly scheduled activities of the class. Your students will benefit from using the digital learning objects by having access to an alternative delivery of the concepts. However, it is expected that after your students have completed each concept using the digital learning objects in the study, you as the instructor will also teach the students the same concept as you would all other concepts in your course.
- At the conclusion of the study, you as the instructor will need to make all of the digital learning objects available on your course Moodle page so that your students can benefit from them by reviewing them as needed.
- There is no cost to you for your participation in the study and you will not receive any compensation.

Risk

- There are no foreseeable risks to being involved in this study.

- All data gathered in this study are to be used for the purpose of the study only. The results of the quizzes or surveys will not be made available to you as the instructor and cannot be used to form part of your students' course evaluation.

Voluntary Participation

- You are under no obligation to participate in this study. Participation is completely voluntary, and you are not obliged to answer any specific questions even if participating in the study.
- Even if you agree to be in the study you can change your mind and withdraw at any time. Your students may also choose to opt out of the study at any time, and they will be given access to a guest Moodle account so that they would still be able to access the digital learning objects and not be disadvantaged by opting out. Students who withdraw from the study may request to have their data withdrawn from the study as well.

Confidentiality & Anonymity

- The results of this research will be used primarily for completing the dissertation requirements for the researcher. However, the results may also be used in presentations and research articles. Neither you nor your students would be identified in any of these.
- All data gathered for this study will be kept confidential with only the researcher and the supervisor able to access your students' personal data. Only summary data will be reported in any publications.
- You and your students will remain anonymous through the study. Each student will be randomly assigned a numbered Moodle account and only the researcher will be able to access the data. Students will be assigned to a random Moodle account by you as the instructor.
- Research data will be kept electronically by the researcher for a period of five years following the completion of the study. All electronic data will be password protected and encrypted and stored on the researcher's computer on a password protected account. No data will be kept that includes student names.
- At the conclusion of the study, as the instructor, you will be asked to gather contact information from your students who wish to view a copy of the final report of the study.
- There is a possibility that the data collected in this study may get used in future research, but if so, it will have to be approved by a Research Ethics Board.

Further Information

- If you have any further questions regarding this study, please do not hesitate to contact:

- The plan for this study has been reviewed for its adherence to ethical guidelines by a Research Ethics Board at the Researcher's University and the Research Ethics Board at the Polytechnic Institute where the data was collected).

APPENDIX 2

Student Participant: INFORMATION LETTER and CONSENT FORM

Study Title: Exploring Digital Learning Objects

Background

- You are being asked to participate in this study because you are the student in a Post-Secondary Calculus course which comprises the sample identified for this study.
- The results of this study will be used in support of the researcher's dissertation for completion of a PhD in Educational Psychology.

Purpose

- The purpose of this research study is to investigate the design of digital learning objects. Digital learning objects are computer based learning tools that are designed to teach or support the learning of a specific concept. Digital learning objects can range from digital images, videos, simulations to interactive computer programs designed to teach a specific concept. In this study, the digital learning objects being investigated are interactive computer programs.
- Research Questions:
    1. Is there a difference in students' learning based on the design of an online digital learning object as a basis of instruction in an introductory calculus class?
    2. Is there a difference in students' learning based on the design on an online digital learning object in relation to the students' comfort level in using a computer?

Study Procedures

- This study will involve five modules that will be accessed through a Moodle course which is the Learning Management System (LMS) that all students at the Northern Alberta Institute of Technology (NAIT) use for the courses. Each module in Moodle will represent one part of the study.
    - The first module will be an online survey that will ask some questions on basic demographic information such as age and gender. The survey will also include a set of questions on about your experience using a computer.
    - The second, third and fourth modules will all be modules that will contain the digital learning objects that will be used in the study. Each digital learning object will contain three parts. The first part will be a lesson on a specific concept in calculus. The second part will be guided practice where you will answer questions on the concept presented in the lesson. The third part of the digital learning object will be a short quiz on the concept presented in the digital learning object.
    - The fifth module in the study will be a short post-study survey designed to gather feedback on your thoughts and experiences while using the digital learning objects.
- Data to be collected.
    - Demographic data collected in the first module

- Gender, age, Citizenship, highest level of math course taken, time since last math course taken, have you completed a calculus course
- A questionnaire which will include questions on your prior experience with using a computer and online learning.

- Post-study survey. After you have completed all of the digital learning objects you will be asked to complete a survey your thoughts and experiences while using the digital learning objects.
- Test scores will be collected from the quizzes taken after completing each of the three digital learning objects. All test scores from the quizzes will be collected during three 1 hour classroom periods. These one hour classroom periods will be part of the regularly scheduled activities of the class, and as such you will be expected to complete the digital learning activities whether they choose to participate in the study. However, data for the study will only be collected about you if you agree to participate in the study. If you choose not to participate in the study you will access the digital learning objects through a guest Moodle account and will not be required to complete the pre and post study surveys.
- There will be no extra time commitment to participate in the study other than the time needed to complete the pre and post study surveys which will take approximately 10 minutes each to complete.

Benefits

- We hope that the information we get from doing this study will help us better understand how to better design digital learning objects to increase learning.
- You will be expected to complete the digital learning objects as part of the regularly scheduled activities of the class whether you participate in the study, and you will benefit from using the digital learning objects by having access to an alternative delivery of the concepts. However, after you have completed each concept using the digital learning objects in the study, your instructor will also teach the students the same concept as he/she would all other concepts in your course.
- At the conclusion of the study, your instructor make all of the digital learning objects available on your course Moodle page so that you can benefit from them by reviewing them as needed.
- There is no cost to you for your participation in the study and you will not receive any compensation.

Risk

- There are no foreseeable risks to being involved in this study.
- All data gathered in this study are to be used for the purpose of the study only. The results of the quizzes or surveys will not be made available to your instructor and will not be used to form part of your course evaluation.

Voluntary Participation

- You are under no obligation to participate in this study. Participation is completely voluntary, and you are not obliged to answer any specific questions even if participating in the study.

- Even if you agree to be in the study you can change your mind and withdraw at any time. You may also choose to opt out of the study at any time, and you will be given access to a guest Moodle account so that you would still be able to access the digital learning objects and not be disadvantaged by opting out. If you choose to withdraw from the study you may request to have your data withdrawn from the study as well.

Confidentiality & Anonymity

- The results of this research will be used primarily for completing the dissertation requirements for the researcher. However, the results may also be used in presentations and research articles. There will not be any data presented in any of these formats that would allow individuals to be identifiable.
- All data gathered for this study will be kept confidential with only the researcher and the supervisor able to access your personal data. Only summary data will be reported in any publications.
- You will remain anonymous through the study. You will be randomly assigned a numbered Moodle account and only the researcher will be able to access the data. You will be assigned to a random Moodle account by your instructor.
- Research data will be kept electronically by the researcher for a period of five years following the completion of the study. All electronic data will be password protected and encrypted and stored on the researcher's computer on a password protected account. No data will be kept that includes your name or other identifiable information.
- At the conclusion of the study your will be given an opportunity to add your name to a list of participants who would like a copy of the final report of the study when it is completed.
- There is a possibility that the data collected in this study may get used in future research, but if so, it will have to be approved by a Research Ethics Board.

Further Information

- If you have any further questions regarding this study, please do not hesitate to contact:
  Todd Sumner:
  E-mail: todds@nait.ca
  Phone: 780.491.1348
- The plan for this study has been reviewed for its adherence to ethical guidelines by a Research Ethics Board at the Researcher's University and the Research Ethics Board at the Polytechnic Institute where the data was collected).

APPENDIX 3

Pre-study Survey

The following are the pre-study survey questions for this study along with the number of response categories in brackets. The pre-study survey consists of two parts, demographic questions and computer experience questions.

Demographic Questions

1. What is your age
2. What is your gender
   - ☐ Male
   - ☐ Female

Computer Experience

3. How many online courses have you taken?
4. Please indicate how much time you spent PLAYING VIDEO GAMES, on average, PER WEEK, during the following:

	Not at all	1 – 3 hours	4 – 6 hours	7 -10 hours	>10 hours
In Recent Weeks	O	O	O	O	O
While in High School	O	O	O	O	O
While in Junior High	O	O	O	O	O
While in Elementary	O	O	O	O	O

5. Please indicate how much time you spent USING SOCIAL NETWORKING (ie, Facebook, Twitter, Instagram, LinkedIn, Pinterest), on average, PER WEEK, during the following:

	Not at all	1 – 3 hours	4 – 6 hours	7 -10 hours	>10 hours
In Recent Weeks	O	O	O	O	O
While in High School	O	O	O	O	O
While in Junior High	O	O	O	O	O
While in Elementary	O	O	O	O	O

6. How would you describe your experience using computers?

No Experience	Little Experience	Average Experience	High Experience
O	O	O	O

Computer Attitude: Used with permission (Nickell & Pinto, 1986)

7. Please answer the following questions.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Computers will never replace human life.	O	O	O	O	O
Computers make me uncomfortable because I don't understand them.	O	O	O	O	O
People are becoming slaves to computers.	O	O	O	O	O
Computers are responsible for many of the good things we enjoy.	O	O	O	O	O

Soon our lives will be controlled by computers.	○	○	○	○	○
I feel intimidated by computers.	○	○	○	○	○
There are unlimited possibilities of computer applications that haven't even been thought of yet.	○	○	○	○	○
Computers are lessening the importance of too many jobs now done by humans.	○	○	○	○	○
Computers are dehumanizing to society.	○	○	○	○	○
Computers turn people into just another number.	○	○	○	○	○
Computers are a fast and efficient means of gaining information.	○	○	○	○	○
The overuse of computers may be harmful and damaging to humans.	○	○	○	○	○
Computers can eliminate a lot of tedious work for people.	○	○	○	○	○
The use of computers is enhancing our standard of living.	○	○	○	○	○
Computers intimidate me because they seem so complex.	○	○	○	○	○
Computers will replace the need for working human beings.	○	○	○	○	○
Computers are bringing us into a bright new era.	○	○	○	○	○
Soon our world will be completely run by computers.	○	○	○	○	○
Life will be easier and faster with computers.	○	○	○	○	○
Computers are difficult to understand and frustrating to work with.	○	○	○	○	○

APPENDIX 4

Post-Test Questions

Digital Learning Object 1 questions:

Please use the following question for the next 4 answers.

A rock is thrown into a pond and creates a circular wave radiating out from where the rock entered the water. The radius (r) of the wave is increasing at a rate of 0.25 m/sec. How fast is the Area (A) of the wave changing when the radius is 20 m?

1) What is the rate you are given in the question?
   a) $dr/dt = 0.25$m/sec
   b) $dA/dt = 0.25$ m/sec
   c) $A/t = 20$ m/sec
   d) $r/t = 20$ m

2) What is the rate you are asked to find?
   a) dr/dt
   b) dA/dt
   c) A/t
   d) r/t

3) Given the equation for an area of a circle is $A = \pi r^2$. Find the derivatives with respect to time.
   a) $dA/dt = 2 \pi r$
   b) $A/t = 2 \pi r/t$
   c) $dA/dt = 2 \pi \mathrm{r} (dr/dt)$
   d) $A = 2 \pi r (dr/dt)$

4) How fast is the Area of the wave changing with respect to time when the radius = 20 m?
   a) 1.57 m^2/sec
   b) 125.6 m^2/sec
   c) 31.4 m^2/sec
   d) 1256 m^2/sec

Please use the following question for the next 2 questions.

The electric resistance (R) (in Ω) of a resistor as a function of temperature (T) (in °C) is R=4.000+0.003T^2. If the temperature is increasing at the rate of 0.1000 °C/sec, find how fast the resistance changes when T = 150°C

5) Find the derivatives with respect to time.
   a) $dR/dt = 0.003T(dT/dt)$
   b) $dR/dt = 4 + 0.006\ (dT/dt)$
   c) $dR/dt = (4 + 0.006T)\ (dT/dt)$
   d) $dR/dt = 0.006\text{T}\ (dT/dt)$

6) How fast is the resistance changing when T = 150°C?
   a) 4.090 Ω/sec
   b) 0.0900 Ω/sec
   c) 71.50 Ω/sec
   d) 0.0450 Ω/sec

7) A metal cube dissolves in acid such that an edge of the cube decreases by 0.50 mm/min. How fast is the volume of the cube changing when the edge is 8.20 mm?
   a) -202 mm^3/min
   b) -6.15 mm^3/min
   c) -101 mm^3/min
   d) -12.3 mm^3/min

Digital Learning Object 2 questions:

1) What is the formula for finding Δy?
   a) $\Delta y = f'(x)\ dx$
   b) $\Delta y = f(x+\Delta x)$
   c) $\Delta y = x_2 - x_1$
   d) $\Delta y = f(x+\Delta x) - f(x)$

2) The differential is defined as:
   a) $dy = f'(x)\ dx$
   b) $dy/dx = f'(x)$
   c) $dy = f(x+\Delta x) - f(x)$
   d) $dy = f(x+\Delta x)\ dx$

3) Find the differential of the following function. $y = 4x^3 - 3x^2 + 4$
   a) $dy = 12x^2 - (6x)\ dx$
   b) $dy/dx = 12x^2 - 6x$
   c) $dy = (12x^2 - 6x)\ dx$
   d) $dy = (4x^3 - 3x^2 + 4)\ dx$

4) Find the differential of the following function. $y = 4(x^2 - 3)^3$
   a) $dy = 24x(x^2 - 3)^2\ dx$
   b) $dy = 12(x^2-3)^2\ dx$
   c) $dy/dx = 24x(x^2 - 3)^2$
   d) $dy = 4(x^2 - 3)^3\ dx$

Please use the following information to answer the next 3 questions

$y = 6x^2 - 3x, \quad x = 6, \ \Delta x = 0.2$

5) What is the differential of the function?
   a) $dy = 12x - 3\ dx$
   b) $dy = 12x - 3$
   c) $dy = (12x - 3)\ dx$
   d) $dy/dx = 12x - 3$

6) Calculate Δy
   a) 212.04
   b) 198
   c) 212.4
   d) 14.04

7) Calculate dy
   a) 13.8
   b) 71.4
   c) 54
   d) -3.6

Use the following information to answer the next 2 questions

$y = (4x^2 - 10)^2 \qquad x = 2,\ \Delta x = 0.01$

8) What is Δy? (rounded to two decimal places)
   a) 37.95
   b) 36.00
   c) 1.95
   d) 1.92

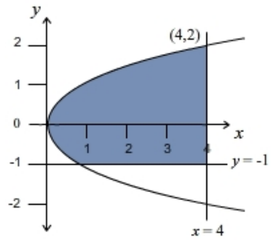
9) What is dy? (Rounded to two decimal places)
   a) 1.95
   b) 1.92
   c) 192.00
   d) -3.20

Digital Learning Object 3 questions:

1) What is the equation you would use to find the area between **two** curves using **horizontal** elements of area?
   a) $A = \int_c^d x\, dy$
   b) $A = \int_c^d (x_2 - x_1)\, dy$
   c) $A = \int_a^b y\, dx$
   d) $A = \int_a^b (y_2 - y_1)\, dx$

2) What is the equation you would use to find the area between **two** curves using **vertical** elements of area?
   a) $A = \int_c^d x\, dy$
   b) $A = \int_c^d (x_2 - x_1)\, dy$
   c) $A = \int_a^b y\, dx$
   d) $A = \int_a^b (y_2 - y_1)\, dx$

3) Why could you not use **vertical** rectangular elements of area for the following?



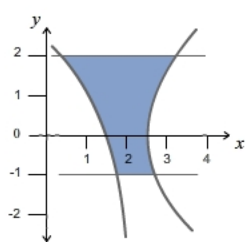
a) The left boundary is unknown
b) Vertical elements cannot be used for parabolas with this orientation
c) There is not one single curve representing the bottom boundary
d) The lower boundary is negative

4) Integrate the following.

$$A = \int_1^4 (x^2 - x + 2)$$

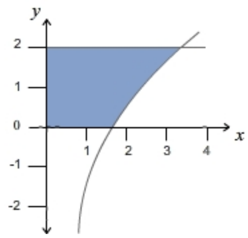
a) $A = 2x - 1 |_1^4$
b) $A = \frac{x^3}{2} - x^2 + 2x \Big|_1^4$
c) $A = 3x^3 - 2x^2 + 2x |_1^4$
d) $A = \frac{x^3}{3} - \frac{x^2}{2} + 2x \Big|_1^4$

5) Which equation would you use to find the area by integration?



a) $A = \int_c^d x\, dy$
b) $A = \int_c^d (x_2 - x_1)\, dy$
c) $A = \int_a^b y\, dx$
d) $A = \int_a^b (y_2 - y_1)\, dx$

6) Which equation would you use to find the area by integration?



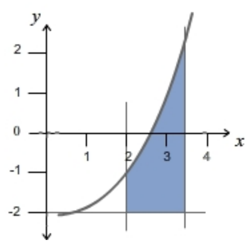
a) $A = \int_c^d x\, dy$

b) $A = \int_c^d (x_2 - x_1)\, dy$

c) $A = \int_a^b y\, dx$

d) $A = \int_a^b (y_2 - y_1)\, dx$

7) Which equation would you use to find the area by integration?



a) $A = \int_c^d x\, dy$

b) $A = \int_c^d (x_2 - x_1)\, dy$

c) $A = \int_a^b y\, dx$

d) $A = \int_a^b (y_2 - y_1)\, dx$

APPENDIX 5

Participant Comments

The following represent the comments submitted by the participants on the last question of the post-study survey. The last question was a field entitled "Additional Comments." The comments have not been edited for grammar, punctuation or spelling.

- Very good tool to be used along with learning from your instructor for people who need that extra help.
- The digital learning objects helped me to understand differentials and area integration by providing visual representations of the steps involved when computing integrals and differentials. I feel that the digital learning objects presented will greatly aid in my final exam for this class. Thank you for providing the opportunity to be involved in this study.
- Prior to this, I had never used a computer based learning object at this level of school/math, so it was a cool and different way to learn. I can see why you're completing your doctorate in this field. Well structured, good job!
- Great experience.
- It was a nice experience.
- possibly add more interaction in the learning lesson portion
- Because Digital learning objects, application of deriavaties, integrating and limits are very easy to understand.
- Good.
- The DLOS was well presented to students but more questions could be added to lengthen the time spent on the DLOS and to ensure the student is understanding all aspects of the topics. There are a lot of concepts covered in each DLOS and a few more questions would allow for greater understating.
- Provide notes package (fill in the blank) in order for students to review once they leave the classroom. There is no motivation to take notes when using the computer.
- I feel that in order to increase the effectiveness of DLO, assignments should be given in order to encourage the students to develop their techniques otherwise the students will neglect these short lectures in time but overall, DLO is very helpful in teaching the basics.
- More feedback would be useful.
- Sometime I feel that there are too many words to read.
- Great if it can mix with classroom instructor.
- Please implement this ASAP.
- I found the material helpful. I liked the individually paced aspect.
- I personally do not learn well from the online learning objects. Could be used as an additional learning supplement for students but not the same as a teacher.
- It was a good thing to learn from because it was easy to understand the procedures.

- It was a good system to use to learn.
- It was quick and easy.
- It was a good experience, in future if we are getting opportunity to learn from digital module, that would be great.
- The instructor in classroom is better than digital learning, but digital helps to get extra practice!!
- It was really nice experience but if possible add voice guidance for DLO that would be great experience.
- The digital learning objects are very good for learning how to do a certain skill or process (such as solving for areas using integration). Because of this I feel like they would be useful when used along side classroom learning - as something extra to help people understand a process. I do not feel that digital learning objects are the most efficient way to teach the theory behind a process (such as why the integral can be used to solve for area). For things such as theory or understanding of concepts and why the process works, I feel like the classroom is a superior learning environment.
- Easy to follow.
- There are some people who are old fashion and can only accept learning trough pencil and paper. as the technology advances I think we should also take advantage of it. digital learning is an other tool that can go into student tool box. when a job is assign, if you don't have the right tools, you might not be precise or will take longer to get the end. I think that digital learning is an essential tool student can use to learn. it allow us to repeat the steps and proses as many times as we need to understand what is going on. if we missed a class or were sick for a week, it it a simple way to catch up. I find that NAIT needs to adapt to digital learning.
- They were good.
- It should display the result of the post study questions.
- I have experience with using My Math Lab and had struggled with its use far more than this on line learning supplement.
- The digital learning objects were helpful for giving a visual representation of the problems presented and showed a clear way to solve the problems.
- The digital learning objects were well organized and I like how they outlined the steps for each question.
- Its aight.
- The DLOS does not assume the student know anything of the topic. It begin teaching the lesson from a beginner level.
- Would be better if we got more attempts on quiz . maybe indicate what section you can reefer back to if answered question wrong.
- DLO was good as an additional tool to use outside of the classroom but would not want to learn a whole course based purely on DLO.
- It was an easy way to learn. Should be implemented to teach online courses.
- It was a decent experience overall.

- It was great, but any questions i had were unable to be answered without an instructor.
- Thanks for opportunity. I personally prefer Digital Learning mixed with some hours lecturer to ask any question or need any explanation. It might work perfectly fine for MATH but not for other courses which need more explanation to understand. However if someone has passed some math courses before it might help perfectly but I believe we still need instructor to understand 100 percent of contents.
- It was a helpful substitute to classroom lectures.
- My eyes kind hurt for watching computer too long then i can not think.
- It was okay.
- Good Stuff.
- Very useful and easy to learn.
- More examples!!!
- Very neat and very easy to understand the topic that has being discuss.
- Digital Learning Objects are really helpful for students and easy to understand.
- The only point I would add is that the animations ie. arrows moving and things moving on the page, made it hard for me to keep concentrated on reading and not be distracted. (In short they made it hard to read)
- i don't think this could ever replace a traditional teacher.
- Should be able to do the digital learning object pre test after the lesson as well as before to see how much you learned.
- The digital learning object is useful for extra information or review but I prefer being taught by an instructor as the main method of learning.
- It's really helpful but in class learning is still the way to go.
- Cool course. I really enjoyed my class it was very helpful.

APPENDIX 6

Summary Review and Full Disclosure

Study Title: Exploring Digital Learning Objects

Thank-you for participating in the study: Exploring Digital learning objects. When you were asked to participate in the study you were made aware of the purpose of the study which was to investigate the design of digital learning objects (DLOs). However, when you were asked to participate, you were not told what design elements of DLOs were being investigated. This was because in order to obtain scientifically valid findings it is important to not fully disclose the details of the study. In particular, if you had knowledge of the variables being investigated it may have influenced your responses and invalidated the data collected.

Full Disclosure
It is important to fully disclose all aspects of the study and make all participants in the study aware of all of the variables being investigated. This is to ensure that all participants are aware of the purpose of the study and to clear up any misconceptions or misunderstandings that may have arisen during the course of the study. Furthermore, full disclosure allows for an opportunity to fully share purpose of the study and how the results will be used to further the understanding the design of digital learning objects.

Study Variables
In this study there were two variables being investigated that participants were not made aware of prior to, or during the study.

1) The first variable was whether embedding feedback into the digital learning objects made a difference in learning. In the study, all of the participants were given identical learning objects except for one difference. That is there were different types of feedback embedded into the learning objects. Each participant was randomly assigned to one three groups with each group getting access to a digital learning object with different types of feedback embedded into the learning object. The types of feedback were
   - Simple feedback – this feedback was simply a response of "correct" or "incorrect" for each question asked in the digital learning object.
   - Positive feedback – this feedback was feedback that gave an explanation of why a **correct** response was correct. In other words, it explained why you got the answer right.
   - Negative feedback – this feedback was feedback that gave an explanation of why an **incorrect** response was incorrect. In other words, it explained why you got the question wrong.

2) The second variable looked at whether computer experience impacted how well students learned from digital learning objects. Whenever using technology for learning, it is important to know whether a participants experience and/or comfort level with using technology has an impact on the results.

To ensure that you were not disadvantaged by participating in the study, the digital learning objects will be made available to all students in the classes who participated in the study. The learning objects will be provided to the class instructor and posted on the class Moodle page for all students to use. The digital learning objects that will be posted on the website will include both the positive and negative feedback from the study.

Re-Consent

Complete this section if, after reading the above full disclosure, you wish to provide re-consent to allow your data to be used in the study. If you do not give re-consent, all data collected about you will be removed from the data set.

I ________________________________ (First and last name) have read the above full disclosure agreement and give consent for the data collected about me during the course of the study to be used in the study.

Participant's Name: (please print) ____

Participant's Signature _________________________________Date: _______________

Study Results

Would you like a copy of the study sent to you once all results have been compiled and the final report completed.

Circle one: Yes No

If yes, please provide an e-mail address where an electronic copy of the study may be sent.

e-mail: ______________________________