

ABSTRACT

FRANZEN, MARISSA MARIE SLOAN. A Study of Trial and Error Learning in Technology, Engineering, and Design Education. (Under the direction of Dr. V. William Deluca and Dr. Aaron Clark)

The purpose of this research study was to determine if trial and error learning was an effective, practical, and efficient learning method for Technology, Engineering, and Design Education students at the post-secondary level. A mixed methods explanatory research design was used to measure the viability of the learning source.

The study sample was twenty-three (N=23) undergraduate students enrolled in an introductory Technology, Engineering, and Design course at North Carolina State University during the 2015 spring semester. Twelve students completed a virtual simulation glider activity that included reading, quizzes, and virtually modeling a glider using a software program called Whitebox Learning. Eleven students completed the same virtual simulation glider activity without the readings and quizzes, and only virtually modeled a glider using Whitebox Learning. Quantitative data was collected from both groups throughout the designing process of their virtual glider model on flight time and the number of iterations created. After the students completed their virtual gliders, qualitative data was collected. Focus group interviews were held for both learning groups in order to collect information on the rationale behind the design process and participants thinking when making choices in each group.

The resultant data implied no significant relationships between number of iterations, beginning flight times, final flight times, or the mean difference of the flight times between

the trial and error learning group and the knowledge application learning group. However, when looking at each group individually, both groups had a positive mean difference between their final flight time and beginning flight times, showing a knowledge gain happening within both groups. Within the focus group interviews, data was collected on the thought process behind a student's decision when creating their virtual glider. The interviews combined with the quantitative data proved a knowledge gain within the trial and error learning group and possibility of it being a viable source for learning.

Technology, Engineering, and Design educators at the post-secondary level should make sure to look into the different types of learning and the most effective methods to educate their students. From the conclusions reached by the researcher, there are several areas suggested for future research. First, a larger random sample should be used for the same study to compare and confirm results. Secondly, a larger sample that includes more females should be conducted to examine any gender differences that could be present. Next, areas of research would be, a study related to the point of convergence within flight times between a knowledge application learning group and a trial and error learning group, and a study related to the number of iterations each student creates within their respected groups, concentrating on valid (in specification) iterations and invalid (out of specification) iterations. Lastly, a study relating to the theme that emerged from the knowledge application learning focus group interview, clarity from the readings, and a study relating to the optimization tool and how it impacts student learning.

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A Study of Trial and Error Learning in Technology, Engineering, and Design Education

by
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TABLE OF CONTENTS

LIST OF TABLES.....	ix
LIST OF FIGURES.....	x
CHAPTER 1: INTRODUCTION.....	1
Rational Choice Theory.....	2
Purpose of the Study.....	3
Justification of Study.....	6
Research Questions and Hypotheses.....	7
Assumptions.....	9
Limitations.....	9
Definition of Key Terms.....	10
Summary.....	12
CHAPTER 2: REVIEW OF LITERATURE.....	14
Introduction.....	14
Trial and Error Learning.....	14
Rational Choice Theory.....	18
Grounded Theory.....	21
Technology, Engineering, and Design Education and Engineering Design Activities.....	22
Virtual Learning and Simulation.....	24
Summary.....	27

CHAPTER 3: METHODOLOGY.....	29
Introduction.....	29
Purpose of the Study.....	29
Research Questions and Hypotheses.....	30
Null Hypotheses.....	32
Research Design.....	33
Target Population.....	38
Sample.....	38
Instrumentation.....	38
Procedure.....	39
Analysis of Data.....	44
Dependent Variables.....	46
Independent Variables.....	47
Control Variables.....	47
Variables.....	48
Summary.....	48
CHAPTER 4: RESULTS.....	50
Introduction.....	50
Description of the Participants.....	52
Analysis of Hypotheses.....	56
Analysis of Focus Group Interviews.....	68
Summary.....	73

CHPATER 5: DISCUSSION.....	75
Introduction.....	75
Summary of Findings.....	75
Research Questions and Summary of the Findings.....	77
Conclusions and Discussion.....	81
Recommendations for Further Research.....	88
REFERENCES.....	91
APPENDICES.....	96
APPENDIX A: INFORMED CONSTENT FORM.....	97
APPENDIX B: GLIDERS PROJECT DESIGN SHEET – KNOWLEDGE APPLICATION LEARNING GROUP.....	99
APPENDIX C: GLIDERS ROJECT DESIGN SHEET – TRIAL AND ERROR LEARNING GROUP.....	100
APPENDIC D: DEMOGRAPHIC SURVEY.....	101
APPENDIX E: FOCUS INTERVIEW TRANSCRIPTION – KNOWLEDGE APPLICATION LEARNING GROUP.....	102
APPENDIX F: FOCUS INTERVIEW TRANSCRIPTION – TRIAL AND ERROR LEARNING GROUP.....	105

LIST OF TABLES

Table 3.1	Research Design.....	34
Table 4.1	Gender Demographics of the Participants.....	52
Table 4.2	Classification Demographics of the Participants.....	53
Table 4.3	Major Demographics of the Participants.....	53
Table 4.4	Previous Knowledge on Simulation Software.....	54
Table 4.5	Previous Knowledge on Gliders.....	55
Table 4.6	Treatment Groups.....	56
Table 4.7	Duration for Beginning and Final Flights by Treatment Groups.....	57
Table 4.8	Descriptive Statistics and Ranks of Gain Scores for Flight Duration.....	58
Table 4.9	Mann Whitney Results for Gain Scores – Test Statistics.....	60
Table 4.10	Descriptive Statistics and Ranks of Iterations.....	61
Table 4.11	Mann Whitney Results for Differences of Iterations – Test Statistics.....	62
Table 4.12	Descriptive Statistics and Ranks of Beginning Flight Duration.....	63
Table 4.13	Mann Whitney Results for Beginning Flight Duration – Test Statistics.....	65
Table 4.14	Descriptive Statistics and Ranks of Final Flight Duration.....	66
Table 4.15	Mann Whitney Results for Final Flight Duration – Test Statistics.....	67

LIST OF FIGURES

Figure 1.1	Mixed Method research Design – Simplified Methodology.....	4
Figure 1.2	Procedures – Quick View.....	6
Figure 3.1	Explanatory Research Design – Quick View.....	37
Figure 3.2	Original Qualitative Interview Questions	43
Figure 3.3	Final Open-ended Qualitative Interview Questions.....	44
Figure 4.1	Graphical Representation of Flight Duration Gain Scores.....	59
Figure 4.2	Graphical Representation of Number of Iterations.....	61
Figure 4.3	Graphical Representation of Beginning Flight Duration Scores.....	64
Figure 4.4	Graphical Representation of Final Flight Duration Scores.....	66
Figure 4.5	Optimization Read-out Example.....	70
Figure 4.6	Summary of Findings and Results – Quick View.....	74
Figure 5.1	Knowledge Application Student Example 1: Engineering Results.....	85
Figure 5.2	Knowledge Application Student Example 2: Engineering Results.....	86
Figure 5.3	Trial and Error Student Example 1: Engineering Results.....	86
Figure 5.4	Trial and Error Student Example 2: Engineering Results.....	87

CHAPTER 1: INTRODUCTION

Virtual learning is a concept that is becoming more and more popular as a mode of teaching. Students are able to learn information, complete new research on their own, and even complete virtual reality simulations all while sitting in one seat in a classroom. Virtual learning environments provide a wide range of learning capabilities by allowing different encounters and interactions for the participant (Piccoli, Ahmad, & Ives, 2001). A student's interest can be sparked and maintained through different activities to work through, while the instructor still can maintain the source of knowledge. Virtual learning brings many benefits to the learning process. It allows students to participate in a non-traditional form of hands-on education through the use of computers, it extends hands-on learning to minds-on skills (Haury & Rillero, 1995). Not only can it explore new worlds that would otherwise be unavailable within an educational classroom, but it is also cost and time efficient.

A main aspect of virtual learning is simulation. Online simulations allow the teacher to bring in a whole new component to teaching by allowing the students to actually work on or control an item from the unit being taught. For example, if students are learning about aircrafts and their properties, at the end of the unit they could take part in a simulation where students are able to actually control and fly an aircraft to extend their learning on the subject and apply the knowledge they have learned into their simulation application. To learn from an experience allows for a more rich understanding of the content being examined (Fox-Turnbull & Snape, 2011).

As an instructor, parent, or administrator it is important to know when a student's learning is being based on knowledge application and when it is being based on a trial-and-error method (Callander, 2011). However, there is a very fine line between the two sources of learning. It is vital to know where knowledge application stops and where trial-and-error begins.

Rational Choice Theory

Behaviorism is a theory based on the observable behavior of people (Kitchener, 1977). A person's environment helps to determine their behavior, with that behavior being the result of a stimulus response. A person's behavior is shaped through positive reinforcement or negative reinforcement. Both types of reinforcement increase the probability of an action or behavior happening again, while both positive and negative punishments decrease the probability that an action or behavior will occur again. In both cases, positive indicates the application of a stimulus, and negative indicates the withholding of a stimulus (Kitchener, 1977).

Under the framework of the behaviorism theory, is the rational choice theory. This theory is based off the rationality a person will always make the most logical decision to provide them with the greatest benefit for their own self-interest (Scott, 2000). The rational choice theory aims to answer two questions. First, how should an individual choose their decision, and second, how can people make sense of the decision that individual chose (Paternotte, 2011). If an individual makes a choice they believe will lead them to the best

consequence, then they are choosing the most optimal decision. As soon as a decision can be seen as optimal, then it can be called rational (Paternotte, 2011).

The explanation of rationale is simply put, in order to maximize personal advantage; an individual will balance the costs against the benefits of a choice. With this thought process all decisions must encounter and go through a rational procedure. It is assumed individuals will choose the best action for their personal gain in regards to the constraints facing them. An individual will be motivated by the wants or goals of their desired outcome. Rational choice theorists state that individuals must take into consideration all alternative courses of action and calculate which will be the best for them. Individuals must anticipate the outcomes of their decisions (Scott, 2000). Under the rational choice theory, it is thought that a rational action acts as its own explanation (Boudon, 2009).

Purpose of the Study

Within education, specifically Technology, Engineering, and Design education, there is a lack of research on the actual learning process of trial and error learning. The purpose of this study is to determine the difference between knowledge application and trial and error learning within a Technology, Engineering, and Design Education classroom. College students in an introductory Technology, Engineering, and Design Education classroom were examined using a virtual glider simulation application to determine if the outcomes of trial and error learning are comparable to the outcomes of knowledge application learning. However, to fully understand if trial and error learning was present, it was imperative to know the thought process and why the student made the selections they did. A

mixed methods research approach was used. Figure 1.1 shows a simplified flow chart of the methodology that was used within the mixed method research design.

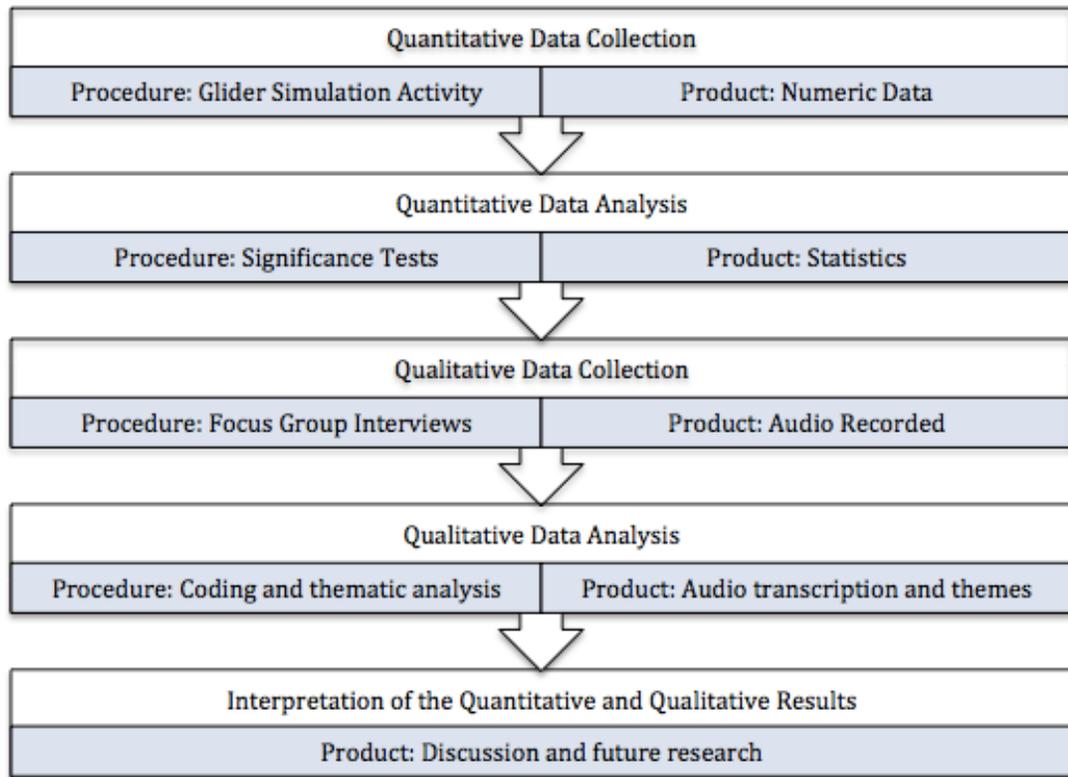


Figure 1.1: Mixed Method Research Design – Simplified Methodology

The reasoning for using a mixed methods study is to ensure a deeper understanding of the data collected, to look at both the results of a classroom project comparing knowledge application and trial and error learning and the reasoning behind why the participants made each decision throughout the process within their different iterations of the glider. Iteration is defined as, the action of repeating a process with an aim of approaching a desired, set goal (Merriam-Webster, 2016). Both quantitative and qualitative data were collected to examine

the depth of the participants learning and the reasoning and rationale behind why the students chose their engineering design decisions within the virtual glider simulation study. A quantitative statistical analysis was completed using a Mann Whitney test with the data collected from the two different learning groups, knowledge application learning and trial and error learning. A Mann Whitney test was used due to the sample being convenient and a small sample size. Additionally, when choosing to use a Mann Whitney U test, there are three assumptions that must be met, each of which agrees with this study's design and data (Laerd Statistics, 2016). The first assumption is that one dependent variable is measured at a continuous or ordinal level. In the case of this study, a continuous variable of time was used when measuring the flight durations. The second assumption is that there is one independent variable that consists of two categorical, independent groups, such as the knowledge application learning group and the trial and error learning group for this study. Finally, the third assumption is an independence of observations, meaning there is no relationship between the observations in each group (Laerd Statistics, 2016). For this study, while both groups are being observed for the same data, there is no relationship between the groups due to a completely separate set of participants and both groups are looked at individually. In addition to the quantitative component, an interview process took place with the participants in the form of focus group interviews; this gave a better understanding of how and why the students made the specific decisions they did throughout the simulation process. Figure 1.2 shows the procedure of the study in a quick list format. The number of participants per group is listed, as well as each step of the study and the amount of time tied to each activity.

- Knowledge Application Learning Group (12 students)
- Trial and Error Learning Group (11 students)
 - 1. Consent Form Signed
 - 2. Glider Design Sheet
 - Outline of process and assignment
 - 3. Glider assignment in respective groups – 1.5 hours
 - Readings, informal quizzes, and tutorial
 - 4. Glider project in respective groups – 2.5 hours
 - Designing and modeling a virtual glider simulation
 - 5. Interviews

Figure 1.2: Procedure – Quick View

This study is important because it provides new information, such as the thought process and design thinking, on the trial and error learning process and how trial and error learning can be used in a classroom setting within the technology education field.

Justification of Study

This study is important because it provides new information on the trial and error learning process and how trial and error learning can be used in a classroom setting within the technology education field. One of the biggest challenges in technology education with virtual simulations is the battle between students learning a material well enough to obtain the knowledge for knowledge application learning. Many times, since students know they are not wasting the resources, they will approach a virtual simulation with a trial and error learning approach rather than the full knowledge application learning approach. While knowledge application learning is a main learning style that provides students with all of the information they need prior to a problem solving assignment, trial and error learning

demonstrates a different level of knowledge and learning gains. When a student enters the real world, facts are not always given prior to the problem needing to be solved. Trial and error learning gives a small glimpse into this reality while still maintaining an educational outlook at solving a problem. As such, the purpose of this mixed methods study was not to document more positives and negatives but to expand upon this knowledge to examine if trial and error learning is an effective, practical, and efficient learning type within a Technology, Engineering, and Design Education classroom at the post-secondary level.

Research Questions and Hypotheses

This study used both quantitative and qualitative research approaches, in order to examine and create a mixed methods study. The study looked at the difference between knowledge application learning and trial-and-error learning. A quantitative statistical analysis, using a Mann Whitney test, occurred using data collected on a virtual glider simulation assignment. Successive qualitative focus group interviews with all participants also took place to discover the reasoning and rationale behind the decision making process in both groups, knowledge application learning and trial and error learning. The following research questions were created for this study to examine both the quantitative and qualitative aspects for a more comprehensive study of the phenomena. The second research question is necessary to fully understand and help to explain the final results found from the quantitative data of research question one. The second research question is the qualitative portion of the study, which allows a full triangulation within the study by comparing results. The researcher is able to comprehend the participants' rationale for creating their choices in

order to recognize if and how the participants were gaining knowledge within each learning group.

Research Question #1: Is there a significant difference between knowledge application and trial-and-error learning in a classroom for introductory Technology, Engineering, and Design Education students at North Carolina State University? The research hypotheses related to the research question are as follows:

H01: There will be no significant difference in the flight duration gain scores between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

H02: There will be no significant difference in the number of iterations created between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

H03: There will be a significant difference for the beginning flight duration score between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

H04: There will be no significant difference for the final flight duration score between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

Research Question #2: How do university students, using either knowledge application learning or trial-and-error learning, make choices when given a virtual glider simulation assignment in an introductory Technology, Engineering, and Design Education classroom?

Assumptions

The following assumptions were made for the study:

1. It was assumed all students had the required knowledge to operate a computer, mouse, and keyboard.
2. With the population of interest being late adolescence and early adulthood, it was assumed the students in TDE 131, Technology through Engineering and Design 1, fell into this category.
3. It was assumed the conditions for completing the study was consistent for all individuals involved.
4. Since the sample was taken from an introductory course, it was assumed all of the students had relatively no experience with gliders and the content covered.
5. It was assumed each student completing the simulation assignment would complete it to the best of his/her ability.
6. It was assumed it was each students first time taking the course TDE 131, Technology through Engineering Design 1.
7. It was assumed all students had no prior degree in this field of study.

Limitations

1. With the study being completed over a multi-day period, it is possible the conditions when completing the project for some students were not the same for others.
2. It is possible some students did not work and complete the glider activity to the best of their abilities.

3. A percentage of the students may have had background knowledge on the topic of glider prior to the study.
4. Since the study was completed in one section of TDE 131, Technology through Engineering and Design 1, the sample was limited in size and participants.
5. Since the study was completed in one section of TDE 131, Technology through Engineering and Design 1, students likely had similar majors or education class status (freshman, sophomore, junior, senior).
6. The sample was limited to students at North Carolina State University; therefore, the results cannot be generalized to students' at other post-secondary institutions.
7. The sample was limited to participants in the program of Technology, Engineering, Design Education; therefore, the results cannot be generalized to students in other program areas.

Definitions of Key Terms

The purpose of this section is to provide various background information, terminology, and/or definitions used in this study.

Explanatory Design – two strands of research are implemented sequentially. Quantitative research is completed first to explain the study's purpose, then qualitative research is completed to explain the results of the quantitative data (Creswell & Clark, 2011).

Glider – an aircraft supported in flight by the dynamic reaction of the air against its lifting surfaces. A glider is free flight, meaning it does not depend on an engine (Merriam-Webster, 2016).

Iteration – the action of repeating a process with an aim of approaching a desired, set goal (Merriam-Webster, 2016).

Knowledge Application – the most significant stage during a knowledge transfer process. It is at this stage individual's use acquired knowledge in order to solve the problem at hand (Boateng & Narteh, 2015).

Learning Treatments – The different tactics of how individuals can learn and process information: by seeing and hearing, reflecting and acting, reasoning logically and intuitively, or analyzing and visualizing (Felder, 2012).

Simulation – Computer-aided three-dimensional design, which is a technological equivalent to traditional hands-on methodology (Smith, 2003)

Technology – Human innovation in action that involves knowledge and processes to develop systems to solve problems and extend human capabilities. The innovation, change, or modification of the natural environment to satisfy wants or needs (International Technology Education Association, 2002).

Technology Education – A study of technology. Provides an opportunity for students to learn about the processes and knowledge related to technologies that are needed to solve problems and extend human capabilities (International Technology Education Association, 2002).

Three-Dimensional – To be able to give the illusion of depth or varying distances, when using an image or pictorial representation on a two-dimensional plane. A model can take many forms, including graphic, mathematical, and physical (International Technology Education Association, 2002).

Trial and Error Learning – A learning process of trying out new strategies, accepting choices that lead to a higher payoff and rejecting choices that are erroneous and do not lead to higher payoffs (Young, 2009).

Triangulation – The use of at least two methods, usually quantitative and qualitative. Both methods address the same phenomena or research problem to ensure the most comprehensive approach (Morse, 1991).

Virtual Learning – A new teaching method allowing learners to perceive the environment, assess situations and performance, performance actions and process through experiences and lessons using various software on the computer (Pimentel, 1999).

Summary

This mixed methods study examined the effectiveness and outcomes of knowledge application versus trial and error learning. The goal of the study was not to compare directly but to identify if trial and error learning is efficient in a technology education setting. The study examined if students were learning when using a trial and error tactic and how that learning occurred. Additionally, an examination of the reasoning and rationale behind the choices made when using both knowledge application and trial and error learning occurred. Specifically, the data collected looked at the comparison of the students' learning curve on both knowledge application and trial and error learning. Following the data collection, the students participated in an interview to learn why they made the decisions they did throughout the simulation building process. Chapter 1 discusses the significance and purpose of the study, chapter 2 presents a relevant literature review and its findings, chapter 3

discusses the methodology used for the study, chapter 4 explains the data and findings of the research, and chapter 5 discusses the findings in relation to the research goals and conclusions.

CHAPTER 2: LITERATURE REVIEW

Introduction

This chapter begins with an examination into trial and error learning. Trial and error learning is based on a process of learning from experiences to build a knowledge foundation (Young, 2009). According to the rational choice theory, trial and error learning applies knowledge and rationale for a student or person to choose the most beneficial choice possible. This rationale of thinking provides that students should be able to learn through trial and error in a process that connects problem solving attempts (Nelson, 2008). Next, research on engineering design activities within Technology, Engineering, and Design Education are examined. In technology education, engineering design activities and projects are constantly incorporated; this research looks into the benefits provided and the reasoning behind these projects. Lastly, research on virtual learning and simulations are examined. Numerous studies have been conducted to look into what constitutes this type of learning including the background, benefits, negative effects, and implementations (Chou & Liu, 2005). The review of research literature, as a whole, provides insight to why it is important to examine trial and error learning in a technology education classroom with the basis of the rational choice theory.

Trial and Error Learning

The concept of trial and error is a method of solving problems. According to the Oxford Dictionary (2014), trial and error is the process of repeated attempts with or without

improvement by learning from failures. When learning through trial and error, the learner is required to make choices amongst numerous alternative outcomes (Noble, 1957). This method is unsystematic and does not follow any sort of methodology, where theoretical insight ends is where the trial and error search begins (Callander, 2011). A person using this method may have little knowledge in the problem area. Reinforcement, extinction, spontaneous recovery, and forgetting are all principles recognized within the theory and method of trial and error learning (Hull, 1939). Biologically, scientists are in the process of examining how trial and error learning affects the brain and neurons. It has been found that trial and error learning induces neuronal selectivity and working memory for task-relevant information. The neurons in the areas of perceptual and memory information support decision-making, showing a relationship to the sequential decision making process of trial and error learning (Rombouts, Bohte, & Roelfsema, 2015).

Although a specific methodology is not uniformly used, trial and error searches are rarely random. The searches are based off learning from experiences, and a concept of knowledge is built upon this learning process. When a person rejects choices that are erroneous, meaning they will not benefit the situation, they can learn by trial and error (Young, 2009). The approach is not careless, but can be organized and logical when manipulating the variables to sort through possibilities. Callander (2011) states, “The search for good outcomes is frequently guided by trial and error (p. 2277).” People will experiment with alternative outcomes, maintaining the latest approach only if it provides an advantage. The seeking out new strategies and ideas allows this method to help a person find new knowledge (Young, 2009).

A modification of trial and error learning is interactive trial and error learning, which accounts for a learning environment with an interactive nature. There are two key elements to interactive trial and error learning. First, a person will keep a new outcome or strategy if and only if it is able to guide to an increase in payoff when experimenting with alternative outcomes. Second, if in a group setting, a person experiences a payoff decrease due to an outcome change by someone else, then the search for a new strategy or outcome will start again (Young, 2009). It is thought the search throughout interactive trial and error is triggered by different states or payoffs and the person expectations of a desired outcome. Both active errors, an unbeneficial outcome, and passive errors, an outcome worse than before, are experienced through interactive trial and error. Trial and error learning is produced through expected reinforcements. Procedural memory, associated with trial and error learning, occurs independent of the reinforcement or error, however, it is boosted by novelty with each new decision made (Doeller & Burgess, 2008).

The learning in the duration of trial and error learning is simple. It does not rely on statistical estimation or observation of others; instead, the person applying the method does not need to know anything about the structure of the item (Young, 2009). Trial and error learning requires relatively low cognitive effort (Huck, Normann, & Oechssler, 2004). Whereas, conditioning is usually evident when there is only one stimulus-response connection, trial and error learning is necessary if there are multiple responses available (Noble, 1957). An experiment with electric shock was completed on humans to test their response to stimuli and motivation to choose and eliminate answers. This experiment proved to have no effect on how humans eliminate errors, proving humans have different drives and

motivations. With this experiment, researchers were able to argue the process of error elimination within humans is a complex form of seizing the outcomes and problems as a whole instead of small pieces (Jones, 1945). Callander (2011) states, “It is said that trial-and-error search begins where the theoretical insight ends. (p. 2277).” With difficult problems to solve, it has the possibility of unknown or little known conditions, this allows for alternative outcomes to choose from. When little is known, theory often provides limited guidance (Callander, 2011).

When comparing novice learners to advanced learners in a trial and error setting, participants at any level follow a similar course (Jones, 1945). The search by trial and error is seldom random or blind, participants learn from their mistakes and experiences. A learner will use accumulated information, from both successes and failures, to direct all other future selections (Callander, 2011). After trial and error training and progression, participants will show a strengthening of the correct tendencies and a weakening of the incorrect tendencies (Hull, 1939). Each time a choice is made, and a learner tries a new tactic, valuable content is exposed. It shows the learner if the option they chose was good or not for the outcome of their particular problem, and likely outcomes of other similar selections. The objective, when using trial and error learning, is to offer insight on when and how learners experiment with their decisions and if they are able to sufficiently learn about the topic at hand to achieve effective outcomes (Callander, 2011). Trial and error learning, in a team or game environment, does not require any information about the rival’s actions. Rather, a strategy can be established and the participant(s) will lead to their own final outcome, whether higher to lower. Each time the participant uses the strategy choice he/she checks the payoffs

associated with the decision. If the payoff is a profitable or beneficial outcome then the movement of the strategy is continued in this direction, if the outcome is a negative payoff then the strategy is reversed and a different direction is taken (Huck et al., 2004)

Trial and error learning interacts with the process of problem solving. In different situations a person uses trial and error learning within a problem solving process. According to Nelson (2008), “trial and error learning interacts with theory modification in the course of problem solving under bounded rationality.” Trial and error learning presents actions that are being considered and targets onto new information about the related phenomena. It involves flexible and unplanned adjustments to the decision making process. As the relevant environment or phenomena emerges, trial and error learning provides insight and innovation with uncertainty and complexity (Sommer & Loch, 2004). Trial and error learning as a problem solving technique is extremely useful when an activity requires a lot of consumable materials. Rather than creating many iterations of a physical product, trial and error learning can be used in the brain storming process (Bowen, DeLuca, & Franzen, 2015). An individual can think through a complete idea and decide if it is worth creating or move on to the next idea before actually using and wasting the consumable materials and resources.

Rational Choice Theory

Behaviorism is a theory based on the observable behavior of people (Kitchener, 1977). It is not a science of human behavior; rather it is the philosophy of human behavior science (Skinner, 2011). A person’s environment helps to determine their behavior, with that behavior being the result of a stimulus response. A person’s behavior is shaped through

positive reinforcement or negative reinforcement. Both types of reinforcements increase the probability of an action or behavior happening again, while both positive and negative punishments decrease the probability that an action or behavior will occur again. In both cases, positive indicates the application of a stimulus, and negative indicates the withholding of a stimulus.

Under the framework of the behaviorism theory, is the rational choice theory. This theory is based off the rationality a person will always make the most logical decision that will provide them with the greatest benefit for their own self-interest. People calculate the costs and benefits of any action or decision prior to deciding what to do (Scott, 2000). The rational choice theory aims to answer two questions. First, how should an individual choose their decision, and second, how can people make sense of the decision that individual chose (Paternotte, 2011). The rational choice theory is predicated on the fact that individuals will actively and efficiently pursue their goals. Individuals may or may not have information regarding their topic, but based on their current understanding of the goal and the alternatives, they will select the course of action with the greatest promise of success (Green & Fox, 2007).

The rational choice theory has been around for decades, but is just recently gaining influence and visibility in many social sciences and related disciplines (Hechter & Kanazawa, 1997). The reasoning behind this lack of support in the past is that rational choice theory has always seemed to get a 'bad press' and a lack of following until recently (Goode, 1997). The aim of the theory is not to look at individual outcomes and explain what a rational individual will do in a certain situation, but rather to examine the social outcomes.

Rational choice theory is a multilevel initiative. At lower levels it examines individual cognitive capacities and values, while at higher levels it examines social structures (Hechter & Kanazawa, 1997). All people employ the rational choice theory on some level without even realizing it (Goode, 1997). It is based on a premise of human objectives and the notion of pursuing aims and goals efficiently within any situation (Green & Fox, 2007). Ideally, the rational choice theory should both examine what choices were made in any situation and then enable anyone to find out the rational behavior behind the choice made (Paternotte, 2011).

The explanation of rationale is simply put, in order to maximize personal advantage; an individual will balance the costs against the benefits of a choice. With this thought process all decisions must encounter and go through a rational procedure. It is assumed individuals will choose the best action for their personal gain in regards to the constraints facing them. An individual will be motivated by the wants or goals of their desired outcome (Scott, 2000). As Goode (1997) stated, “if we observe what seems to us to be chaotic behavior, whether among human being under stress or among cells being attacked by a virus, we are likely to call it some kind of pathology – and then seek its rationale.” Rational choice theorists state that individuals must take into consideration all alternative courses of action and calculate which will be the best for them. Individuals must anticipate the outcomes of their decisions (Scott, 2000). Under the rational choice theory, it is thought that a rational action acts as its own explanation. When an individual makes a decision, if that decision making process can be explained then it is rational, and if it is rational then it can be explained (Boudon, 2009).

A key component of the rational choice theory is optimization. Optimization happens when individuals make choices and take action on their decisions after assessing all of the pros and cons of each alternative option. The individual should then choose the action with the greatest benefit. The rational choice theory provides a justification of purposeful and important human actions. If an individual makes a choice that is optimal then it is deemed to be rational (Moll & Hoque, 2006). The rational choice theory relies on the fundamental principle that people should make optimal decisions (Paternotte, 2011). If an individual makes a choice they believe will lead them to the best consequence, then they are choosing the most optimal decision. As soon as a decision can be seen as optimal, then it can be called rational.

Grounded Theory

Grounded theory is a systematic research method within qualitative research. The result of this method provides results from the analysis of data through a discovery of theory. The grounded theory approach provides themes to become apparent by the grouping of codes within conceptual categories that reflect commonalities among the data (Glaser & Strauss, 1967). Grounded theory can be used to explore both experiences and actions in order to explain social processes through the development of theories (Charmaz, 2006). Within grounded theory, interpretation of actions and interactions of people are derived and given meaning.

By using the grounded theory, reappearing themes can be recognized and used to interpret qualitative data in a meaningful manner. Theory that is empirically grounded in the

collected data allows explanations and descriptions on the process of interest within the topic at hand (Jeon, 2004). Grounded theory is generated systematically using inductive methods through observation. It is about research and detection through direct contact with the data (Glaser & Strauss, 1967).

When grounded theory is focused on how the researcher interprets the data, it is a type of grounded theory called constructivist grounded theory. Researchers are able to discover, identify, and interpret relationships and patterns in the data. Based off of these relationships and patterns, researchers develop categories and themes within the data (Charmaz, 2006). A researcher must study the participant's actions, intentions, and look closely at their meanings within what is said.

Technology, Engineering, and Design Education and Engineering Design Activities

The field of Technology, Engineering, and Design Education has undergone a vast amount of changes in its curriculum, scope, missions, and principles throughout its history. In order to meet the demands of the ever-changing technological society and industrial innovation, Technology, Engineering, and Design Education has transitioned through philosophical and methodological changes. The most recent opportunity to change and develop within the Technology, Engineering, and Design Education field stems from an alignment and closer relationship with the engineering community (Dearing & Daugherty, 2004). Both engineering and engineering design are included in the *Standards for Technological Literacy* (International Technology Education Association, 2002). A student's

task understanding is related to their planning and cognitive strategies within an engineering design activity (Lawanto, 2011).

Mentzer (2011) states, “Technology Education has a successful track record in providing hands on experiences, but may strengthen its ties to an integrative STEM education approach by leveraging natural connections that exist” (p. 131). By aligning engineering design activities, such as building model bridges or rockets, it allows “students to understand the impacts of engineering development and become literate about the technological world around them” (Dearing & Daugherty, 2004, p. 8). Technological literacy is a vital educational goal, and the ability to make meaningful decisions in relation to society and technology is essential. By utilizing tools specific to engineering in conjunction with technology education’s experiential approach helps to expand and facilitate a student’s technological literacy (Mentzer, 2011). Just to be able to understand the problem is an important step and design activity for students (Lawanto, 2011). Engineering design projects are an excellent way to allow students the opportunity to relate to the real world through classroom activities but on a level that can still be structured, supervised, and explained. As Lawanto (2011) states, “solving an engineering design problem is a structured and staged process” (p. 4). Engineering design challenges apply engineering principles to solve real-world problems by using an active, hands-on methodology through practical application (Mentzer, 2011). Not only do successful engineering and classroom projects help students to understand real-world applications, but also do natural catastrophes or engineering failures. Educators embrace studies of engineering failures as a means for a pedagogical strategy that

teaches students' different learning standards and how to design within realistic constraints (Rose & Hunt, 2012).

Technology, Engineering, and Design Education involves the process of creativity. In order, to develop creative thinking it is vital to practice activities that help to promote design and innovation. The development of design and technology curricula is premised on the importance of designing and the worth of the contingent action of creative thinking (Middleton, 2005). Technology, Engineering, and Design Education is an avenue for developing general problem solving skills, modeling and prototyping skills, creative thinking, and analytical reasoning (Dearing & Daugherty, 2004). Engineering and invention show promising tactics for how to apply creativity in design and technology education classes (Middleton, 2005). Promoting creative thinking is one of the major reasons for including design and technology programs within school curricula, it is an important concept for students to learn and evolve (Mentzer, 2011). Engineering design challenges bridge the divide between technology education and engineering because of the opportunity they provide to think creatively, focus efforts on a design project, all while applying engineering principles.

Virtual Learning and Simulation

Virtual learning is a new component in Technology, Engineering, and Design Education with a number of advantages in terms of convenience and flexibility, however, the effectiveness has yet to be determined (Piccoli, Ahmad & Ives, 2001). Online technology

has a gripping impact on teaching and learning (Chou & Liu, 2005). Virtual learning allows students to participate in a non-traditional form of hands-on education through the use of computers, extending hands-on learning to minds-on skills (Haury & Rillero, 1995). Piccoli, Ahmad & Ives (2001) state, “Internet technologies are having a significant impact on the learning industry” (p. 401). Virtual learning allows interactions and the sharing of knowledge with other participants and provides a broad range of resources. The open system of virtual learning allows participant interaction through synchronous and asynchronous communication. As a result, students have a larger chance to express and articulate their knowledge and understanding (Chou & Liu, 2005).

A computer, a product of technology, is a machine students should become familiar with and feel comfortable using to solve problems (Luna, 1998). It is another tool in our arsenal of tools humans are able to use in order to extend human capabilities. Computer-aided three-dimensional design is a technological equivalent to traditional hands-on methodology. Three dimensional computer aided design is able to teach students advanced mathematics and physics concepts, through different software and programs available. Simple machines, mechanical advantage, related mathematics, and problem solving are all examples of integration of mathematics and sciences in technology virtual learning software (Smith, 2003). By using three-dimensional computer-aided design software students are able to use the computer to make a representation of any physical object. Along with three-dimensional software programs, computers use simulation software in conjunction. Simulations allow students to see how various functions are interrelated and help contribute to success (Lamoureux, 2009). Virtual learning environments allow interaction and different

encounters with the participant in order to provide a wide range of learning capabilities (Piccoli, Ahmad, & Ives, 2001). Students are able to use these programs to experiment with different scenarios, problem solving, and decision making with little risk and without wasting resources.

Virtual learning also provides benefits to the student consisting of time and place independents. It allows for flexibility of access, multi-sensory experiences, interactivity via email, chat, or video conferencing, and affordability due to the little to no cost for resources (Deal, 2002). The emphasis of virtual learning is on self-control, to diffuse thinking models, vary viewpoints, and instill self-sufficient thinking. Thus, from a performance point of view, it is reasonable to propose virtual learning is beneficial (Chou & Liu, 2005). Additionally, virtual learning is efficient, technology-based training takes much less time to complete relative classroom instruction (Deal, 2002). Individuals using simulation programs are able to experiment with different types of scenarios and problem solving tactics. Additionally, the individual is able to make a decision with minimal consequence and risk in order to save and ensure resources are not being wasted (Bowen et al., 2015). Along with all of its benefits, virtual learning environments also include drawbacks. Much of literature involving technology highlights both the potential value and the setbacks of feelings of isolation, frustration, anxiety, and confusion (Piccoli, Ahmad, & Ives, 2001). Lack of interest or reduced interest in the subject or learning effectiveness can also be a setback with virtual learning (Chou & Liu, 2005). Factors of the effect of virtual learning mainly deal with technology itself. The quality and reliability of technology, along with the easy access to appropriate hardware and software equipment, are important determinants of learning

effectiveness. Hardware and software compatibility, along with connectivity and technology skills, are common problems when it comes to virtual learning success (Deal, 2002).

Virtual learning helps to promote self-efficacy. Implications show that higher learner control allows students to feel proud they have the capability to use learning tools and learn independently, in turn leading to higher self-efficacy (Chou & Liu, 2005). Virtual learning is able to provide a way to merge the best features of real-world information navigation. Online navigation paired with the memory of places or visual cues permit quick searches, sorting, and swift cross-referencing (Bouras, Philopoulos & Tsiatsos, 2001). Virtual simulations are devices that help to extend human capabilities (Bowen et al., 2015).

Summary

This literature review covers trial and error learning, rational choice theory, grounded theory, technology, engineering and design education and engineering design activities, and virtual learning and simulations. The major conclusions of this literature review are engineering design activities allow students to explore real-world problems in an engaging way especially using virtual learning and simulations. Trial and error learning and technology education are a purposeful pairing. Many technology, engineering, and design education activities require a lot of consumable materials and substantial time to complete. By using virtual learning and simulations, trial and error learning can be incorporated and no consumable materials will be wasted (Bowen et al., 2015). In this chapter, links between the connections of trial and error learning and the rational choice theory were explored and confirmed. The rational choice theory indicates a learner will choose the best outcome for

his or her own gain in a situation, this thought process connects to how a student learns through trial and error learning within a classroom. If using trial and error learning, a student should choose the best possible outcome in order to gain knowledge and advance. Finally, a justification of why grounded theory is the best method for analyzing the focus group interviews for the study. Grounded theory explores qualitative research and identifies the patterns and relationships in order to create common themes within the data analysis.

The combination of the literature reviews help to support the reasoning and the importance for the study. A look into trial and error learning within Technology, Engineering and Design education can be a valuable tool to post-secondary educators. The theories used, grounded theory and rational choice theory, help to explain and deepen the understanding of the outcome of data within an empirical mindset.

CHAPTER 3: METHODOLOGY

Introduction

It is believed by many that trial and error learning is not an effective learning process. However, it has been said in many different studies and situations that, although not efficient, trial and error learning can produce successful results (Callander, 2011). The review of literature led to believe there are components of trial and error learning that have not been fully examined in an educational field. One component included the comparison between knowledge application learning and trial and error learning within a classroom setting, with respect to Technology, Engineering, and Design Education students. The rational choice theory led to believe learning through trial and error can result in the same knowledge gain as knowledge application. A student will make the most rational choice to choose the most beneficial outcome for his or her own self-interest (Paternotte, 2011).

Purpose of the Study

Within education, specifically Technology, Engineering, Design education, there is a lack of research on the actual learning process of trial and error learning. The purpose of this study is to determine the difference between knowledge application and trial and error learning within a Technology, Engineering, and Design Education classroom. College students in an introductory Technology, Engineering, and Design Education classroom were examined using a virtual glider simulation application to determine if the outcomes of trial and error learning are comparable to the outcomes of knowledge application

learning. However, to fully understand if trial and error learning was present, it is imperative to know the thought process and why the student made the selections they did. The reasoning behind this informed the educator of the classroom if their students understand the topic or not. A mixed methods research approach was used. The reasoning for using a mixed methods study was to ensure a deeper understanding of the data collected, to look at both the results of a classroom project comparing knowledge application and trial and error learning and the reasoning behind why the participants made each decision throughout the process. Both quantitative and qualitative data were collected to examine the depth of the participants learning and the reasoning and rationale behind why the students chose their engineering design decisions within the virtual glider simulation study. A quantitative statistical analysis was completed using a Mann Whitney test with the data collected from the two different learning groups, knowledge application learning and trial and error learning. In addition to the quantitative component, an interview process took place with the participants in the form of focus interviews; this gave a better understanding of how and why the students made the specific decisions they did throughout the simulation process. This study is important because it provides new information on the trial and error learning process and how trial and error learning can be used in a classroom setting within the technology education field.

Research Questions and Hypotheses

This study was examined using both quantitative and qualitative research approaches, creating a mixed methods study. The study looks at the difference between knowledge

application learning and trial-and-error learning. A quantitative statistical analysis, using a Mann Whitney test, occurred using data collected on a virtual glider simulation assignment. Successively, a qualitative focus interviews with all participants took place to discover the reasoning and rationale behind the decision making process in both groups, knowledge application learning and trial-and-error learning. The following research questions were created for this study to examine both the quantitative and qualitative aspects for a more comprehensive study of the phenomena:

Research Question #1: Is there a significant difference between knowledge application and trial-and-error learning in a classroom for introductory Technology, Engineering, and Design Education students at North Carolina State University? The research hypotheses related to the research question are as follows:

H01: There will be no significant difference in the flight duration gain scores between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

H02: There will be no significant difference in the number of iterations created between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

H03: There will be a significant difference for the beginning flight duration score between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

H04: There will be no significant difference for the final flight duration score between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

Research Question #2: How do university students, using either knowledge application learning or trial-and-error learning, make choices when given a virtual glider simulation assignment in an introductory Technology, Engineering, and Design Education classroom?

Null Hypotheses

Null Hypothesis #1. There will be no significant difference between the flight duration gain scores for the knowledge application learning group and the trial and error learning group. A non-parametric Mann Whitney statistical test was used to determine if differences exist between variables **KAdiff** for the knowledge application learning group and **TEdiff** for the trial and error learning group.

Null Hypothesis #2. There will be no significant difference between the number of iterations created for the knowledge application learning group and the trial and error learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between the variables **KAiteration** for the knowledge application learning group and **TEiteration** for the trial and error learning group.

Null Hypothesis #3. There will be a significant difference for the beginning flight duration score between the knowledge application learning group and the trial-and-error learning group. A non-parametric Mann Whitney statistical test will be used to determine if

differences exist between the variables **KAflight1** for the knowledge application learning group and **TEflight1** for the trial and error learning group.

Null Hypothesis #4. There will be no significant difference for the final flight duration score between the knowledge application learning group and the trial-and-error learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between the variables **KAflight2** for the knowledge application learning group and **TEflight2** for the trial and error learning group.

Research Design

The research design for this particular study followed a mixed methods design. Mixed methods is defined as a research design or methodology utilizing an integration or mixture of both quantitative and qualitative research in a single study in order to fully understand the information gained within the study (Johnson, Onwuegbuzie, & Turner, 2007). The study will look at relationships between knowledge application and trial and error learning; therefore a deductive theoretical drive with a dominant look into quantitative research was applied (Morse, 2003). The nomenclature of the mixed methods research design was QUAN → qual (big quantitative, little qualitative). This design allowed for an emphasis on the quantitative method to be conducted followed by a qualitative method. The studies were completed sequentially with a deductive theoretical drive, although induction was also used in the qualitative component (Morse, 2003). The study looked at how students in a technology, engineering, and design education classroom learn through both knowledge application of content learned and trial and error learning treatments. Prior to the study, the

researcher met with an expert in the field of mixed methods studies. The expert and researcher thoroughly explored all aspects of the study to ensure a mixed methods research design was best for the study and to assess and establish validity within the mixed methods design. Table 3.1, below, demonstrates the research design and the utilization of both quantitative and qualitative research methods.

Table 3.1: Research Design

		Treatment	Quantitative Data Collection (iterations and flight duration)	Qualitative Data Collection (interviews)
Knowledge Application Learning Group	R	X	O ₁	O ₂
Trial and Error Learning Group	R	Y	O ₁	O ₂

R: Assignment of the subjects to either the knowledge application learning group or the trial and error learning group

X: Students were given the readings, quizzes, and tutorials in Whitebox Learning prior to creating their virtual glider simulation.

Y: Students were only given the tutorials on Whitebox Learning prior to creating their virtual glider simulation.

O₁: Quantitative data was collected through Whitebox Learning on the students' number of iteration and flight duration.

O₂: Qualitative data was collected through an interview process with each of the participants.

In the case of this study, triangulation was used in order to complete a more comprehensive study of the phenomena (Morse, 1991). Both quantitative and qualitative research methods allowed a deeper look into the topic of knowledge application and trial and error learning. In this study, sequential triangulation was used. Morse (1991) defines sequential triangulation as, “sequential triangulation is used if the results of one method are essential for planning the next method.” The research design of this study completed the quantitative data collection before beginning with the qualitative data collection. The qualitative interviews of the students were based off of the quantitative results of each participant. A sequential triangulation of results was used; the qualitative research provided explanation for particular parts of the quantitative research (Morse, 2003). As with a triangle, triangulation has three parts or corners to help better explain and take bias away from the results of the research. Within this research, the three corners consisted of the quantitative data, the qualitative data, and the connection between the two sets of data to further explain and understand the quantitative results. By completing all three parts within the research, all data and results are compared against one another to fully divulge the essence behind each participants reasoning and the correlation to their outcomes.

The mixed methods research for this study follows a mixed methods explanatory design. Figure 3.1, below, is a quick view diagram for the study using explanatory research design. Both quantitative and qualitative research was collected to help explain one another and integrate together for an interpretation of the entire analysis (quantitative and qualitative) (Vrkljan, 2009). The main pathway with this study was a quantitative study, however, a supplemental component of qualitative research was added in order to enhance the

understanding and explanation of the quantitative component (Morse, 2003). The quantitative data was collected first to address the study's purpose, and then sequentially, qualitative data was collected to help explain the quantitative results (Creswell & Clark, 2011). Once the qualitative data was analyzed it was integrated into the findings of the quantitative data or core component in order to explain those findings completely and inform the research questions.

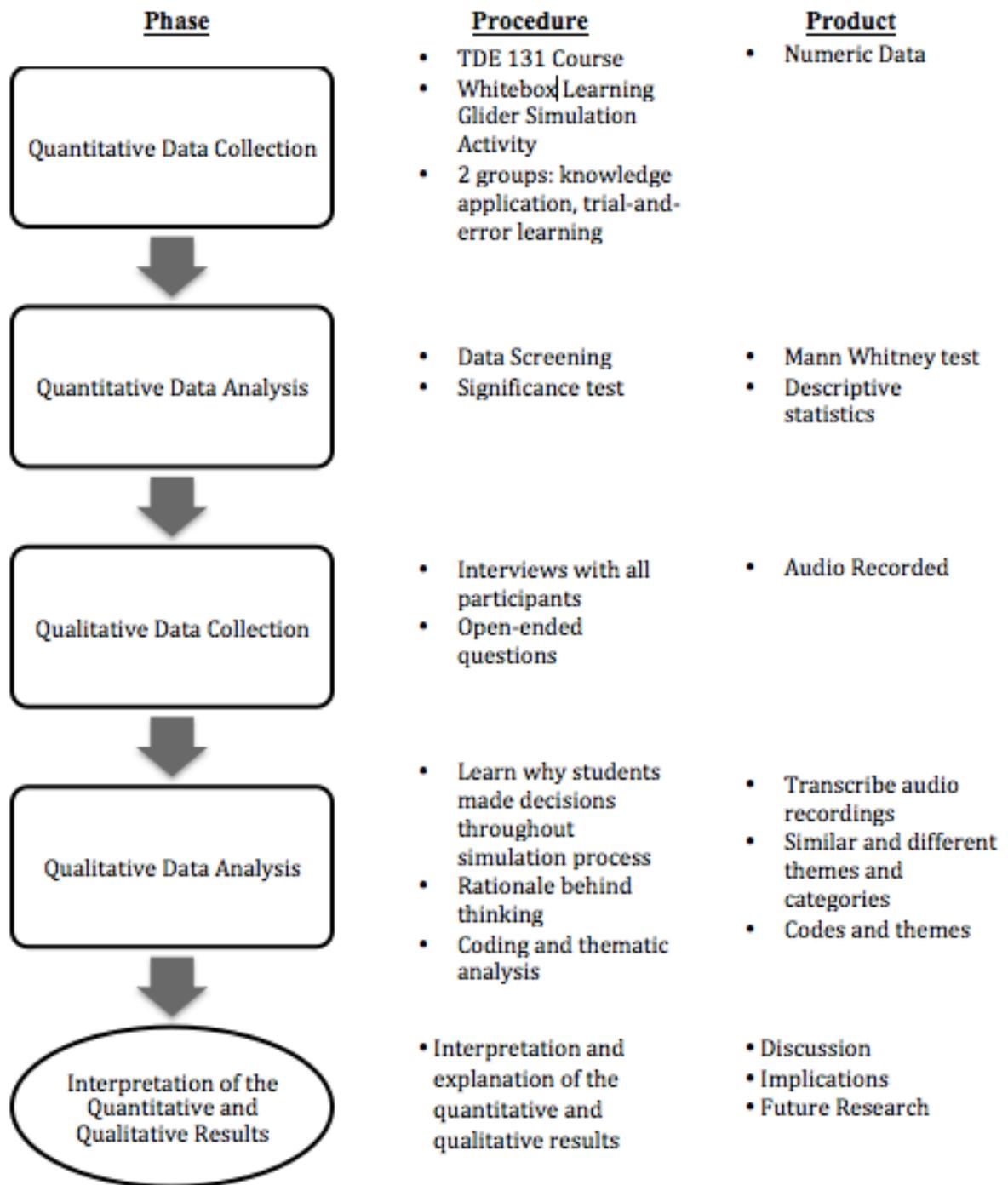


Figure 3.1: Explanatory Research Design – Quick View

Target Population

The intent of the study was to examine both knowledge application and trial and error learning treatments comparatively within a college course. The target population for this study were individuals in late adolescence and early adulthood enrolled in a post-secondary institution. This population is of interest to teachers in Technology, Engineering, and Design Education courses at the post-secondary level.

Sample

A convenience sample of undergraduate students enrolled in an introductory Technology, Engineering, and Design Education course at North Carolina State University during the 2015 spring semester was selected and used. The class roll of TDE 131 – Technology through Engineering and Design 1 was used as the sampling frame. The complete population of the course was used for the study.

Instrumentation

For this study, the measurement instruments used were number of iterations when creating a glider simulation, duration of flight of the glider, and follow up interviews with all participants. The students were broken up into two groups, a knowledge application learning group and a trial and error learning group. Both groups completed the glider unit in a software program called Whitebox Learning. Whitebox learning has built in assessments and data collection of all participants using the program. Within Whitebox Learning, the students were given usernames and passwords allotted for TDE 131. These usernames then reported

data collectively in a group, in order to directly compare the results of the different student's outcomes. The data of interest used as a measurement instrument was the number of iterations each student created within each learning group (variable: **iterationdiff**), the duration of the beginning flight for the simulation glider for each learning group (variable: **flight1diff**), the duration of the final flight for the simulation glider for each learning group (variable: **flight2diff**), and the duration of flight gain scores for the simulation glider in each learning group (variable: **gaindiff**). The number of iterations and flight duration was compared individually to detect any outliers, then grouped to their respective assigned learning groups and compared to look at each group and the different learning processes collectively.

Procedure

To begin, the students within the study were the students of the undergraduate Technology, Engineering, and Design Education course TDE 131 at North Carolina State University. The students were both male and female who were 18 years or older. They have some prior background knowledge in Technology, Engineering, and Design Education, but were not masters of the subject or the activity planned. The class was broken up into two groups, a knowledge application learning group and a trial and error learning group, to create as even a sample as possible. The sample course TDE 131 was made up of 23 students, meaning the knowledge application learning group had 12 students and the trial and error learning group had 11 students. The students were assigned randomly to each group. To avoid cross contamination of the groups within the study, each group was designated a

separate room to work in throughout the study process. All students involved signed an informed consent form (see Appendix A) and was aware of the study being conducted. All participants completed a demographic survey (see Appendix D). This survey collected information on the students' backgrounds, such as college major, education class (freshman, sophomore, junior, senior), and gender.

The students were given a glider design project sheet (see Appendix B and C), in respect to their assigned learning group, to outline the contents that were asked of them and inform the students of the timing outline for each step of the process. The students completed a gliders unit; readings, quizzes, and simulation on a software program called Whitebox Learning. Whitebox Learning provides a modular type unit of study to the students on a designated content area. The content area for this study focused only on gliders.

The knowledge application learning group completed readings and informal quizzes through Whitebox Learning. Within the Whitebox Learning program, students began the glider unit and followed the breadcrumb titles completely through to the end to ensure all the readings, quizzes, and tutorials had been covered. The readings and quizzes covered the complete background knowledge and content area of gliders. Once the readings were complete, the knowledge application group were given tutorials on how to create a virtual simulation of a working glider. The tutorials covered all of the different controls within Whitebox Learning and referenced the content learned in order to use knowledge application while building the simulation. The goal of the glider simulation was to create a glider with the longest flight duration.

Meanwhile, the trial and error learning group were not given any readings or quizzes on the glider content. The trial and error learning group went straight into the virtual simulation program tutorials. However, while completing the tutorials, this group did not receive any references to readings or content. The trial and error learning group had the tutorials printed out to ensure no exposure to the readings and quizzes. Once the tutorials were completed, the participants within this group clicked on the Engineering & Airshow tab within the Whitebox Learning program to begin construction on their virtual simulation glider. This group used a trial and error technique within the simulation program to build a glider with the longest flight duration.

Participants were given 1.5 hours, to complete any readings, quizzes, or tutorials and 2.5 hours to complete the modeling, regardless of the group to which they were assigned. Once all of the students completed their projects in both groups, the results were recorded and an analysis was completed on the differences between the knowledge application learning group and the trial and error learning group. The analysis was based on the number of iterations created and flight duration. The data was turned into a quantitative data format in order to carry out the statistical tests to look at the spreads and significance tests. The statistical test that was used for this study was a Mann Whitney test. The reasoning for using a Mann Whitney test was because the sample the study used was a convenient sample, not a random sample. Additionally, the Mann Whitney test is a nonparametric test of the null hypothesis that two populations, the knowledge application learning group and the trial and error learning group, are the same against an alternative hypothesis (Laerd Statistics, 2013). Following the completion of the gathering of data and performing the statistical tests, the

researcher met with a statistician, an expert in the field. The researcher met with a statistician in order to assess and establish validity for all of the data collected and processed.

Following the quantitative statistical analysis, a qualitative interview with the participants occurred. The format of the interviews followed focus group protocol. The focus groups were used to gather opinions and thought processes of the participants. There were two focus group interviews, one for the trial and error group and one for the knowledge application learning group. The interviews were audio-recorded, transcribed, and coded. The researcher used these interviews to attempt to gain a certain perspective from each particular group (Krueger, 2009). Focus group interviews are well suited and a viable source for qualitative studies including grounded theory (Webb & Kerven, 2001). The purpose of the interview was to gain knowledge of the reasoning behind each student's choices made. The interview gave a deeper insight to the rationale of each student's selection when creating his or her virtual simulations. This rationale and reasoning furthered the knowledge gained from the quantitative data analysis and added logic and an explanation to why the students made each choice they did and created each iteration. The rational choice theory indicates an individual will make the best choice for his or her own interest (Scott, 2000). The interview questions helped to determine the student's line of thinking in relation to their own costs and benefits on the glider simulation activity. Markers were used to connect and relate the interviews better to the Rational Choice Theory.

Two researchers were responsible for conducting each focus group interview, one researcher served as the facilitator and the other researcher served as note taker. The focus group interviews were audio recorded, in addition to notes taken, in order to cross-check

data. Before conducting the focus group interviews, the researcher met with an expert in the field of qualitative research as an assessment and establishment of validity. Figure 3.2, below, shows the five original questions the researcher developed for the focus group interviews. After meeting and discussing with qualitative expert, these five questions were condensed into two all encompassing questions instead. The qualitative expert helped to direct the wording of the questions to better extract the correct information from the participants during the interviewing process. Figure 3.3, below, shows the two main open-ended interview questions asked of the participants during the interview process. The interview was set up to allow the main questions to lead to other probing questions for answers relating to the participants learning groups and the rational choice theory. After the facilitator asked each question, additional probing questions were asked based off answers given for the purpose of clarification and confirmation. The interviews took approximately 15 minutes to complete for each focus group. After the completion of the interviews, each interview was transcribed (see Appendix E and F) in order to look for common themes and patterns.

1. What was the participant's choice making process when creating a simulation?
2. Did the participant use knowledge application or trial and error learning?
3. How and why did the participant make the choices they chose?
4. Why did the participant stop creating iterations?
5. What number iteration was the final product they chose to keep and turn in?

Figure 3.2 Original Qualitative Interview Questions

1. What factors informed your design decisions as it relates to creating your glider simulations?
2. How were your design decisions influenced by your previous choices?

Figure 3.3: Final Open-ended Qualitative Interview Questions

By using focus group interviews, the members of the groups are there to expand upon other participants responses, add clarity to group responses, and to provide member checking. In order to gather accurate data concerning the two types of learning applications, it was important to establish harmony among group members. For the purpose of this study, the researcher felt that focus group interviews were appropriate.

Analysis of Data

This study can be characterized as an explanatory mixed methods study with an emphasis on quantitative research. In a quantitative aspect, data was collected from the Whitebox Learning software, looking at the flight duration and number of iterations for each student. The data was analyzed using a statistical analysis program to run the Mann Whitney test in order to analyze the beginning and final flight duration scores and number of iterations created between the two groups. A Mann Whitney test is a nonparametric test of the null hypothesis that two populations, the knowledge application learning group and the trial and error learning group, are the same against an alternative hypothesis (Laerd Statistics, 2013). It compares the differences between two independent groups when the dependent variable is either ordinal or continuous, for this study the dependent variables are continuous (Laerd

Statistics, 2016). The study aimed to provide reliable, consistent, and accurate statistical analyses.

In a qualitative aspect, data was collected in the form of focus group interviews with the participants, after the quantitative data was collected. A content analysis of the interview responses was audio-recorded, transcribed, and coded to collect data. A grounded theory approach was used to analyze the focus group results. Grounded theory is an inductive, comparative iterative method used predominantly as a method of data analysis (Glaser & Strauss, 1967). The grounded theory approach provides themes to become apparent by the grouping of codes within conceptual categories that reflect commonalities among the data (Charmaz, 2006). In this study, reappearing themes were for looked for from the focus group interview responses by looking at the transcribed recordings and notes taken during each interview session. The transcriptions and field notes taken were reviewed, coded, and then grouped into concepts and themes. Open coding was used to discover the emerging themes, word repetitions and key-words-in-context (KWIC) were techniques used to help code the qualitative data (Ryan & Bernard, 2003). . It is important to take note of words or concepts that occur and reoccur, the more the same concept occurs in a text; the more likely it is a theme. When conducting the KWIC coding, word-counting techniques were used to produce word lists of unique words used a multiple number of times (Ryan & Bernard, 2003). After conducting the word counts, these key words were then systematically examined within the context surrounding it to gather the key phrases to establish and identify the themes present. Through these codes generated from grounded theory, markers were determined which better related the themes to the Rational Choice Theory. The markers established were strategy,

design, and rationale. This allowed the study to be driven forward towards the participants' rationale within each grouping.

Once themes were discovered it was important to link the information gained back to the quantitative data. The whole reasoning for performing the qualitative portion was to supplement and give better viewpoints of the quantitative data analyses. These themes helped to understand the results of the quantitative analyses in a contextual and expressive manner from the participants. It helped to give an insight to the reasoning and rationale of how the gliders were created and tested for both the knowledge application learning group and the trial and error learning group.

In order to produce reliable results that could be verified and validated, both differential and inferential statistical analyses were conducted. By using both methods, validation of the data could occur by cross verifying each methods results with the other. Using two different methods to test the same phenomena, in this case, the difference between knowledge application and trial and error learning, allowed the study to overcome any weakness or intrinsic bias that could come from a single method.

Dependent Variables

The dependent variables of the study are the difference scores in flight duration, gain scores, and number of iterations created of the virtual glider simulations between each learning group. Five dependent variables were examined: the difference between **KAflight1** (average of beginning flight duration for the knowledge application learning group) and **TEflight1** (average of beginning flight duration for the trial and error learning

group) – **flight1diff**, the difference between **KAflight2** (average of final flight duration for the knowledge application learning group) and **TEflight2** (average of final flight duration for the trial and error learning group) – **flight2diff**, the difference between **KAdiff** (difference of KAflight2 and KAflight1) and **TEdiff** (difference of TEflight2 and TEflight1)– **gaindiff**, and the difference between **KAiteration** (average number of iterations in the knowledge application learning group) and **TEiteration** (average number of iterations in the trial and error learning group) – **iterationdiff**. Participants in the knowledge application learning group received readings, quizzes, and tutorials before creating their virtual glider simulations in order to collect **KAflight1, KAflight2, and KAiteration**. While, participants in the trial and error learning group only received the tutorial treatment before creating their virtual glider simulations in order to collect **TEflight1, TEflight2, and TEiteration**.

Independent Variables

Within the study, the independent variables were the two different learning groups, knowledge application learning and trial and error learning. The purpose of the study was to examine the difference between the two learning types, knowledge application and trial and error learning.

Control Variables

The control variables within the study were the students and the class in which the study was given, TDE 131 – Technology through Engineering and Design 1.

Variables

group – 1-knowledge application learning group, 2-trial and error learning group

KAflight1 – Average of beginning flight duration for the knowledge application learning group

KAflight2 – Average of final flight duration for the knowledge application learning group

TEflight1 – Average of beginning flight duration for the trial and error learning group

TEflight2 – Average of final flight duration for the trial and error learning group

KAdiff – Difference between **KAflight2** and **KAflight1**

TEdiff – Difference between **TEflight2** and **TEflight1**

gaindiff – Difference between **KAdiff** and **TEdiff**

KAiteration – Average number of iterations in the knowledge application learning group

TEiteration – Average number of iterations in the trial and error learning group

iterationdiff – Difference between **KAiteration** and **TEiteration**

Summary

This chapter described the method and research design that was used to execute the purpose of the study and test the research hypotheses. The study was a mixed methods research design, with quantitative analysis and a qualitative interview. Sequential

triangulation was used in order to ensure confidence in the results, through both quantitative and qualitative methods. Using both techniques to allow cross verification of the separate methods outcomes validated the data. The test instrument used was the outcomes of the virtual glider simulation. The interviews used a grounded theory qualitative approach to collect information on the reasoning behind each student's decision making process, in regards to the rational choice theory. The target population were individuals in late adolescence and early adulthood. The sample was of undergraduate students enrolled in an introductory Technology, Engineering, and Design Education course during the spring semester of 2015 at North Carolina State University. A statistical analysis program was used to analyze the data collected. Each section within this chapter discussed the aims, scope, and strategy for this study.

CHAPTER 4: RESULTS

Introduction

The purpose of this study was to explore and determine the difference between knowledge application and trial and error learning within a Technology, Engineering, and Design Education classroom at the post-secondary level. The results from all students enrolled in the introductory class TDE 131 (n=23) were investigated, in regards to determining if the outcomes of trial and error learning were comparable to the outcomes of knowledge application learning. This chapter presents the data relevant to knowledge application learning and trial and error learning within a Technology, Engineering, and Design Education introductory course.

The data is looked at in two different manners in order to follow a mixed methods approach. First, quantitative data is analyzed to examine the depth of the participants learning and, second, qualitative data is analyzed to examine the rationale behind the participants' choices throughout their glider simulation study. The study followed a mixed methods research design, specifically an explanatory design. Both quantitative and qualitative researches were collected to help explain one another for an interpretation of the entire analysis (Vrkljan, 2009). The main pathway of this study was a quantitative study with a supplemental component of qualitative research added in order to enhance the understanding and explanation of the quantitative component (Morse, 2003). The quantitative data was collected first to address the study's purpose, and then sequentially, qualitative data was collected to help explain the quantitative results (Creswell & Clark,

2011). Once the qualitative data was analyzed it was integrated into the findings of the quantitative data to explain those findings completely and inform the research questions.

Within this research study it was necessary to complete a mixed methods study in order to fully understand the phenomena. When looked at individually, the quantitative data gave the numbers and results of how each participant and group performed but the researcher was unable to understand reasoning and why those results happened. Meanwhile, the qualitative data gave a good understanding of the design thinking for each participant and group but could not output any concrete numbers or simulation results to correlate to the participants thinking and designing process. For this reasoning, a mixed methods research design was necessary in order to complete a full comprehensive study. Using both methods together allowed the researcher to examine the statistical outputs and the design thinking concepts together cohesively to gather results and conclusions.

The target population for this study consisted of (n=23) students currently enrolled in an introductory Technology, Engineering, and Design Education course, TDE 131. Participants were randomly assigned to a group, informed throughout the course, and signed an informed consent letter (see Appendix A). Useable responses were collected from the full population of (n=23) students who responded and participated within the learning activities, simulations, and interviews (response rate 100%).

This chapter is divided into three sections. The first section exhibits the demographic data on the participants. Participation in the study was broken down by gender, classification, major, previous knowledge, and treatment group. The second section in this chapter exhibits data related to research and results compared between the knowledge

application learning group and the trial and error learning group. Research hypotheses 1 through 4 are tested and the results reported to whether the findings were statistically significant. The third section in this chapter exhibits data related to the group interviews conducted with each learning group. Qualitative data is collected and the results are reported to further understand the reasoning and rationale behind the quantitative results. The chapter concludes with an overall summary of the findings.

Description of the Participants

Table 4.1 displays the data on the participants in the study by gender.

Table 4.1: Gender Demographics of the Participants (N=23)

Gender	No. of Participants	Percent
Male	15	65.0
Female	8	35.0
Total	23	100.0

Of the 23 participants males represented 65.0%, which proved to be the predominant gender. There were approximately two times as many males as females participating in the study. This is probably due to the fact that majors requiring Technology, Engineering, and Design Education courses (from which the sample was drawn) attract considerably more male students than female students.

Table 4.2 displays the classification demographics of the participants within the study.

Table 4.2: Classification Demographics of the Participants (N=23)

Class	No. of Participants	Percent
Freshman	0	0
Sophomore	5	21.7
Junior	17	74.0
Senior	1	4.3
Total	23	100.0

Within the sample (N=23), all participants, except for one outlier, were classified as a sophomore or junior classification. This could be due to the fact of TED 131 being an introductory course and showing up early in their curricular display for sophomores (21.7%) and perhaps major changes for junior (74.0%).

Table 4.3 displays the major demographics of the participants within the study.

Table 4.3: Major demographics of the participants (N=23)

Major	No. of Participants	Percent
Education	18	78.4
Engineering	2	8.6
Other	3	13.0
Total	23	100.0

When considering each participants major they were currently enrolled, a huge majority of the participants were in the Education field (78.4%). Most likely, if the students were enrolled in the introductory class for Technology, Engineering, and Design Education they were already a part of the major and enrolled in Education to benefit from the course. This introductory course is a required course for the major of Technology, Engineering, and Design Education.

Table 4.4 displays the breakdown of any previous knowledge or experience the participants had with simulation software outside of what was learned in the course.

Table 4.4: Previous knowledge on simulation software

Knowledge	No. of Participants	Percent
None	18	78.3
Minimal	5	21.7
Plenty	0	0
Total	23	100.0

Within the sample (N=23), the spread of previous knowledge on simulation software was very minor. About three-fourths of the students (78.3%) did not have any prior knowledge or experience with simulation software, and those who did (21.7%) only had minimal experience. This is important for the study because it helps to take away biases of skill sets within the simulation software.

Table 4.5 displays the breakdown of any previous knowledge or experience the participants had with gliders prior to the study.

Table 4.5: Previous knowledge on gliders

Knowledge	No. of Participants	Percent
None	14	60.9
Minimal	9	39.1
Plenty	0	0
Total	23	100.0

Within the sample (N=23), the spread of previous knowledge on gliders was slightly higher than the simulation software but still very minimal. About two-thirds of the students (60.9%) did not have any prior knowledge or experience with gliders, and those who did (39.1%) only had minimal experience. This is important for the study because it helps to take away biases of previous background knowledge of gliders.

Table 4.6 shows the breakdown of participants for each treatment group.

Table 4.6: Treatment Groups (N=23)

Group	No. of Participants	Percent
Knowledge Application Learning	12	52.2
Trial and Error Learning	11	48.8
Total	23	100.0

Students were assigned to two treatment groups, knowledge application learning or trial and error learning. The students were randomly assigned to each group within the course of TDE 131 using a random number generator. Twelve students (52.2%) were assigned to the knowledge application learning group and eleven (48.8%) were assigned to the trial and error learning group.

Analysis of Hypotheses

Null Hypothesis #1. There will be no significant difference between the flight duration gain scores for the knowledge application learning group and the trial and error learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between variables **KAdiff** for the knowledge application learning group and **TEdiff** for the trial and error learning group.

Table 4.7 looks at the descriptive statistics of both the beginning flight duration and final flight duration for both the knowledge application learning and trial and error learning groups.

Table 4.7: Duration for Beginning and Final Flights by Treatment Group

	Variable	N	Beginning Flight Duration Mean	Beginning Flight Duration Standard Deviation	Final Flight Duration Mean	Final Flight Duration Standard Deviation	Mean Difference
Knowledge Application Learning	Group 1	12	3.12	2.73	6.67	2.19	3.55
Trial and Error Learning	Group 2	11	2.11	1.73	6.76	1.78	4.64

Table 4.7 looks at both the beginning flight duration and final flight duration for both the knowledge application learning and trial and error learning groups. Within the glider simulator the participants used, Whitebox Learning, once a glider was created the students tested the glider by virtually flying it to record the flight time. A gliders success was based off of the length of time, or duration, the glider stayed in the air. As the students created their different iterations of their simulation glider, the software collected the data for each version created. Of this data, for the purpose of this study, there was a focus on the beginning flight duration (or first glider created flight time) and the final flight duration (or last glider created flight time). The table displays the mean and standard deviation for each group.

The data was analyzed using JMP statistical analysis program. The table shows the variable KAflight1 = 3.12, KAflight2 = 6.67, TEflight1 = 2.11, and TEflight2 = 6.76. The mean difference is discussed as variable, KAdiff (3.55) and TEdiff (4.64).

Table 4.7 shows that the knowledge application learning group started with a mean score of 3.12 and ended with a mean score of 6.67, this was a mean difference of 3.55 second. Meanwhile, the trial and error learning group started with a mean score of 2.11 and

ended with a mean score of 6.76, this was a mean difference of 4.64 seconds. Even though both the knowledge application learning and the trial and error learning group had similar final flight duration measurements, the trial and error learning group had a larger gain or mean difference between the beginning flight and final flight times.

Table 4.8 displays the descriptive statistics of gain scores and the Mann Whitney Ranks for flight duration for both learning groups, the data was analyzed using JMP and SPSS statistical analysis programs. Figure 4.1 shows a graph representation of both the knowledge application learning group and the trial and error learning groups' descriptive statistics for the flight duration gain scores. The bar graph represents the frequency, while the box-and-whisker plot along the bar graph represents the minimum, first quartile, median, third quartile, and the maximum to give a better representation of the spread of data.

Table 4.8: Descriptive Statistics and Ranks of Gain Scores for Flight Duration

	Variable	N	Mean	Standard Deviation	Mean Rank	Sum of Ranks
Knowledge Application Learning	Group 1	12	3.55	2.281	10.58	127.00
Trial and Error Learning	Group 2	11	4.64	2.122	13.55	149.00

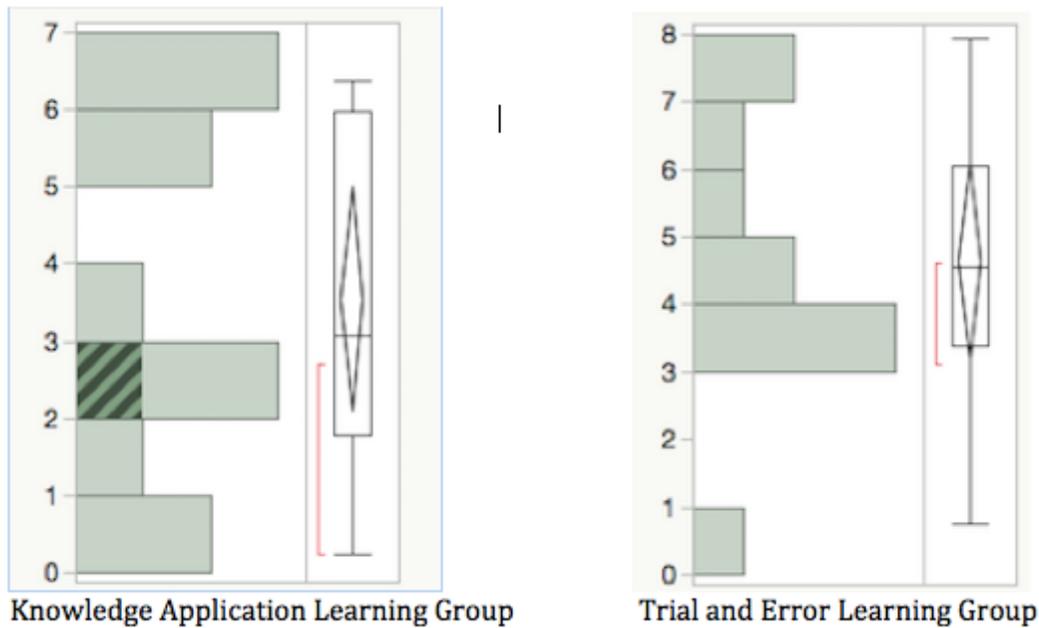


Figure 4.1: Graphical Representation of Flight Duration Gain Scores

The graphs from figure 4.1 allow the researcher to see the large spread this set of data had. Both sets of data had a standard deviation of over two, which shows a slight inconsistency between all of the participants within each group. The trial and error learning group is balanced or closer to being symmetrical, while the knowledge application learning group is skewed left but with a lower median than the trial and error learning group. This shows the trial and error learning group more consistently had larger flight duration gain scores.

Table 4.9 displays the results for the Mann Whitney statistical test for variable gaindiff, the difference in the mean scores for the knowledge application learning group (KAdiff) and the trial and error learning group (TEDiff). The data was analyzed using the SPSS statistical analysis program.

Table 4.9: Mann Whitney Results for Gain Scores – Test Statistics

	Gain
Mann Whitney	49.00
Wilcoxon W	127.00
Z	-1.046
Asymp. Sig (2-tailed)	0.295

The p-value for the gain scores across the knowledge application learning group and the trial and error learning group is $p = 0.295$, meaning it is not significant. This shows the difference in the gain scores across the knowledge application learning and the trial and error learning groups were not significant.

The analysis indicated there was not a significant difference for the differences between the variables **KA**diff and **TE**diff at $\alpha = 0.05$. The findings support Research Hypothesis 01.

Null Hypothesis #2. There will be no significant difference between the number of iterations created for the knowledge application learning group and the trial and error learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between the variables **KAiteration** for the knowledge application learning group and **TEiteration** for the trial and error learning group.

Table 4.10 displays the descriptive statistics and the Mann Whitney Ranks of iteration for both learning groups, the data was analyzed using JMP and SPSS statistical analysis programs. Figure 4.2 shows a graph representation of both the knowledge application

learning group and the trial and error learning groups' descriptive statistics for the number of iterations created.

Table 4.10: Descriptive Statistics and Ranks of Iterations

	Variable	N	Mean	Standard Deviation	Mean Rank	Sum of Rank
Knowledge Application Learning	Group 1	12	17.25	11.038	10.46	125.50
Trial and Error Learning	Group 2	11	24.36	16.627	13.68	150.50

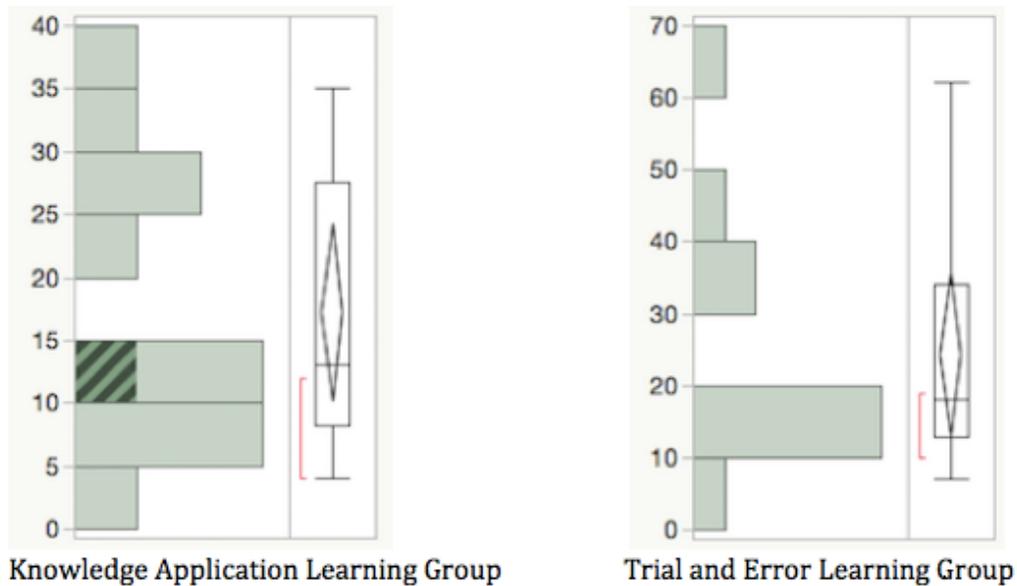


Figure 4.2: Graphical Representation of Number of Iterations

The graphs from figure 4.2 allow the researcher to see the extremely large spread of data. The knowledge application learning group had a standard deviation of over eleven, while the trial and error learning group had a standard deviation of over sixteen. Both of

these groups show a massive spread of data, which allowed the researcher to note the variability of the number of iterations from the participants in each group. Both groups are skewed right, with the trial and error learning group showing a larger skew. This shows both groups had a greater number of participants with their number of iterations above the median line.

Table 4.11 displays the results for the Mann Whitney statistical test for variable *iterationdiff*, the difference in the iterations created of the knowledge application learning group (*KAiteration*) and the trial and error learning group (*TEiteration*). The data was analyzed using the SPSS statistical analysis program.

Table 4.11: Mann Whitney Results for Differences of Iterations – Test Statistics

	Iterations
Mann Whitney	47.50
Wilcoxon W	125.50
Z	-1.139
Asymp. Sig (2-tailed)	0.255

The p-value for the difference of iterations across the knowledge application learning group and the trial and error learning group is $p = 0.255$, meaning it is not significant. This shows the difference in the number of iterations created across the knowledge application learning group and the trial and error learning group was not significant.

The analysis indicated there was not a significant difference for iteration diff, the difference between the variables KAiteration, and TEiteration, at $\alpha = 0.05$. The findings support Research Hypothesis 02.

Null Hypothesis #3. There will be a significant difference for the beginning flight duration score between the knowledge application learning group and the trial-and-error learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between the variables **KAflight1** for the knowledge application learning group and **TEflight1** for the trial and error learning group.

Table 4.12 displays the descriptive statistics and Mann Whitney Ranks of beginning flight duration for both learning groups, the data was analyzed using JMP and SPSS statistical analysis program. Figure 4.3 shows a graph representation of both the knowledge application learning group and the trial and error learning groups' descriptive statistics for the beginning flight duration scores.

Table 4.12: Descriptive Statistics and Ranks of Beginning Flight Duration

	Variable	N	Mean	Standard Deviation	Mean Rank	Sum of Ranks
Knowledge Application Learning	Group 1	12	3.12	2.732	13.17	158.00
Trial and Error Learning	Group 2	11	2.11	1.730	10.73	118.00

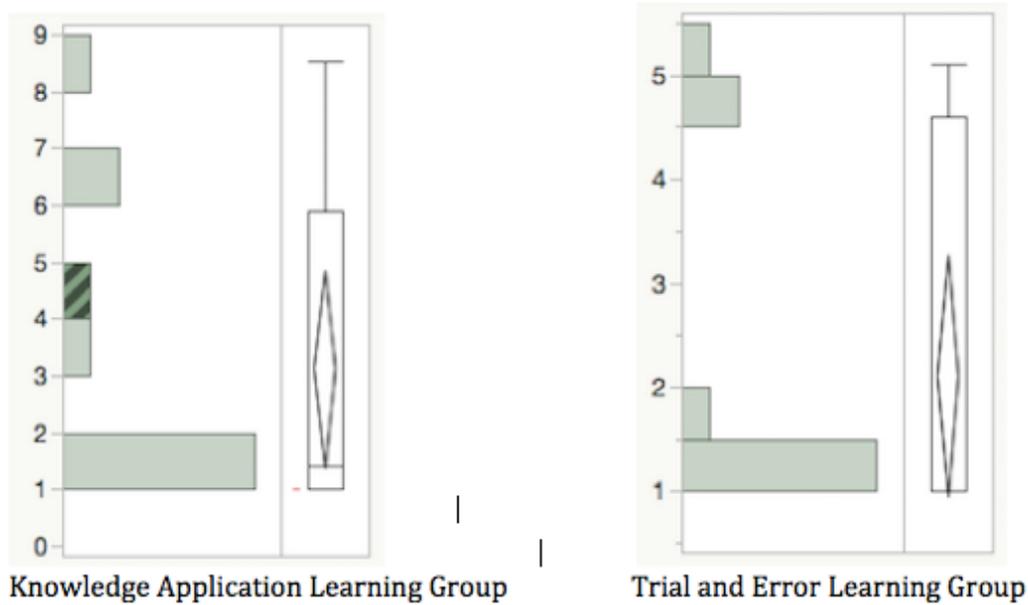


Figure 4.3: Graphical Representation of Beginning Flight Duration Scores

The graphs from figure 4.3 allow the researcher to see the spread of the data. The knowledge application learning group had a standard deviation of over two, while the trial and error learning group had a standard deviation of over one. The trial and error learning group shows a smaller spread, meaning the all the participants in the group started with a similar beginning flight duration, whereas, in the knowledge application group the beginning flight durations had a larger range. Both groups are skewed right, with the knowledge application learning group showing a larger skew. This shows both groups had a greater number of participants with their beginning flight duration above the median line.

Table 4.13 displays the results for the Mann Whitney statistical test for the beginning flight duration scores, KAflight1 and TEflight1. The data was analyzed using the SPSS statistical analysis program.

Table 4.13: Mann Whitney Results for Beginning Flight Duration – Test Statistics

	Beginning Flight Duration
Mann Whitney	52.00
Wilcoxon W	118.00
Z	-0.913
Asymp. Sig (2-tailed)	0.361

The p-value for the beginning flight durations across the knowledge application learning group and the trial and error learning group is $p = 0.361$, meaning it is not significant. This shows the difference in the beginning flight duration scores across the knowledge application learning group and the trial and error learning group was not significant.

The analysis indicated there was not a significant difference for the beginning flight duration scores between the variable KAflight1 and TEflight1 at $\alpha = 0.05$. The findings did not support Research Hypothesis 03.

Null Hypothesis #4. There will be no significant difference for the final flight duration score between the knowledge application learning group and the trial-and-error learning group. A non-parametric Mann Whitney statistical test will be used to determine if differences exist between the variables **KAflight2** for the knowledge application learning group and **TEflight2** for the trial and error learning group.

Table 4.14 displays the descriptive statistics and Mann Whitney Ranks of final flight duration for both learning groups, the data was analyzed using JMP and SPSS statistical

analysis program. Figure 4.4 shows a graph representation of both the knowledge application learning group and the trial and error learning groups' descriptive statistics for the final flight duration scores.

Table 4.14: Descriptive Statistics and Ranks of Final Flight Duration

	Variable	N	Mean	Standard Deviation	Mean Rank	Sum of Ranks
Knowledge Application Learning	Group 1	12	6.67	2.193	11.96	143.50
Trial and Error Learning	Group 2	11	6.78	1.781	12.05	132.50

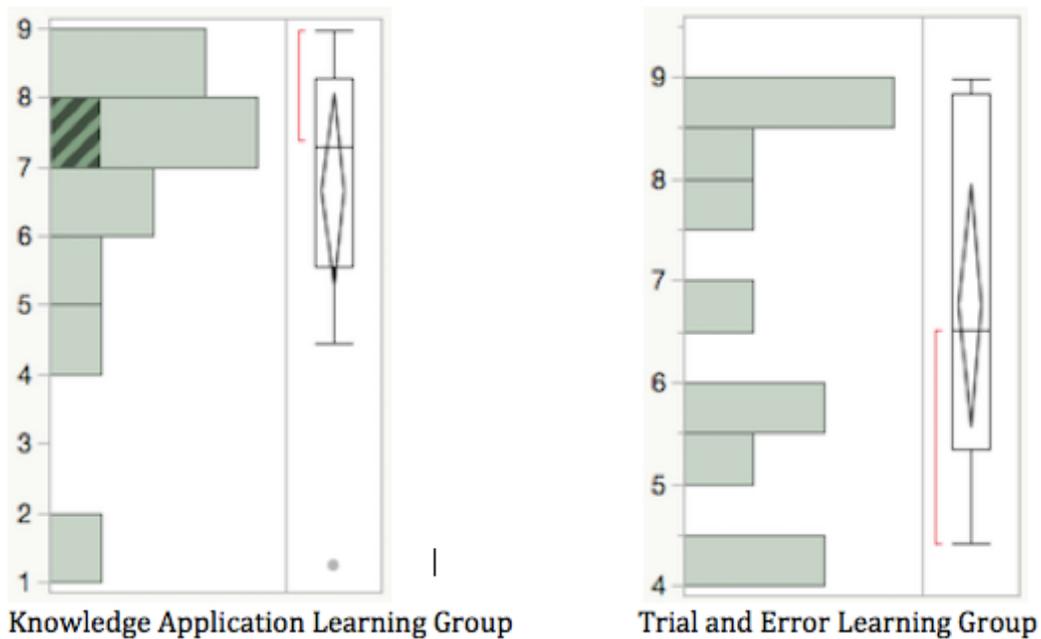


Figure 4.4: Graphical Representation of Final Flight Duration Scores

The graphs from figure 4.4 allow the researcher to see the spread of the data. The knowledge application learning group had a standard deviation of over two, while the trial and error learning group had a standard deviation of over one. The trial and error learning group shows a smaller spread, meaning the all the participants in the group ended with a similar final flight duration, whereas, in the knowledge application group the final flight durations had a larger range. Both groups are skewed left, with the trial and error learning group showing a larger skew. This shows both groups had a greater number of participants with their final flight duration below the median line.

Table 4.15 displays the results for the Mann Whitney statistical test for the final flight duration scores, KAflight2 and TEflight2. The data was analyzed using the SPSS statistical analysis program.

Table 4.15: Mann Whitney Results for Final Flight Duration – Test Statistics

	Final Flight Duration
Mann Whitney	65.50
Wilcoxon W	143.50
Z	-0.031
Asymp. Sig (2-tailed)	0.975

The p-value for the final flight durations across the knowledge application learning group and the trial and error learning group is $p = 0.975$, meaning it is not significant. This shows the difference in the final flight duration scores across the knowledge application learning group and the trial and error learning group was not significant.

The analysis indicated there was not a significant difference for the final flight duration scores between the variable KAflight2 and TEflight2 at $\alpha = 0.05$. The findings supported Research Hypothesis 04.

Analysis of Focus Group Interviews

As the focus group interviews were being conducted, it was clear there was a slight disconnect between the participants and understanding design thinking. The purpose of the interview questions were to dive deep into the thought process and the design thinking of each participant in order to understand their reasoning for making each of their choices throughout the simulation. When each focus interview question was asked there was a moment of silence while the participants processed the question and tried to make sense of what was being asked. In both groups it took a small discussion and other probing questions for the participants to fully understand the main question being asked of them within their design thinking process. The probing questions helped to guide them towards fully answering the main interview questions and recognize how to think and explain their process through a design-thinking format.

The results of the grounded theory approach to analyzing the focus group responses provided two common themes from each group and one individual theme per each group, with a total of four themes overall from the two focus group interviews. The two common themes shared between both the knowledge application learning group and the trial and error learning group were (a) the use of optimization and (b) previous experiences. The knowledge application learning group individually produced a theme of (c) clarity from the

readings, while the trial and error learning group produced an individual theme of (d) change and patterns.

Within both groups, the common theme of the use of optimization was a large impact. The meaning behind this theme is located in the software. When the students were building their gliders, regardless of their group, they had access to a tool called “optimization.” This tool in the program allowed the builder to see different areas of success and failure within their design. It is a read-out within the Whitebox Learning software that shows the balance of variables within the glider created. Figure 4.5, below, shows a sample image of a read out from the optimization tool. By using this tool participants were able to check the weight of their plane, along with the lift, drag, roll, pitch, and yaw. These terms were all learned within the background reading for the knowledge application learning group, and were new terms the trial and error learning group had to decipher and make sense of throughout their building process. The function of the optimization tool allowed the builder to note which aspects of their glider was successful and stable or, which could use improvements due to it being unstable. The trial and error learning group did not have the background knowledge for each of these terms, but could still use the optimization tool to help them gain knowledge and gain a deeper understanding of how gliders worked in order to add the terms to their knowledge base.



Figure 4.5: Optimization Read-out Example

The four themes found are discussed below in detail.

Common Themes:

A. The Use of Simulator Optimization Tool

In the analysis of data from the focus group interviews, a theme appeared as a result of almost all of the participants mentioning and discussing the importance and use of the optimizations tool within their glider design. Participants from both groups talked about how beneficial the optimization tool was and how it was a main factor in creating a successful glider simulation:

I had the optimization graph next to it so I could make sure the drag was minimal and everything was as optimal. (Knowledge Application Learning Group)

... I changed around values until it was all optimal and at the best (Trial and Error Learning Group)

Participants from both groups discussed once they discovered the optimization tool, it increased their flight time significantly.

Mine jumped from 1 second to 7 seconds after I found the optimized tool. (Knowledge Application Learning Group)

I used the optimization tool, so I just kept changing stuff until it was at the optimal levels. (Trial and Error Learning Group)

B. Previous Choices

From both groups, participants seemed to agree that paying attention and learning from previous choices was a huge factor in creating a successful glider simulation. In each group, students mentioned slowly changing their glider design, one step at a time, based off the notes they took from previous design choices:

I would try to fix one thing at a time. Once I would change something, I would test it to see if it worked better or worse. If it did work better than I would keep it and then fix everything to make it better. And if it didn't work then change that and see how it worked the next time. (Knowledge Application Learning Group)

I would only change one thing at a time, and if that didn't work then I would change it back and I would change something else. (Trial and Error Learning Group)

I based it off both but more mainly off the previous one. You have visible data that you can change; you can see what needs to be changed. (Trial and Error Learning Group)

Additionally, other participants from each group mentioned changing many aspects at a time, but still focusing on previous experiences. They would keep a record of all of their previous creations in order to have something to compare or fall back on:

I would just keep the different versions. Because when I was trying to tweak one thing I would go through a couple versions and I would realize the first version I had, 3 iterations back was more effective. I would go back to that and change that and see

if it could improve from there. So, keeping and having a log of how each one performed (Knowledge Application Learning Group)

I kept a log. (Knowledge Application Learning Group)

...I saved one of them to compare it with my new design and then my new design ended up winning so I did not have to go back to the other one. But I did that a few times. (Trial and Error Learning Group)

Individual Themes:

Knowledge Application Learning Group:

C. Clarification from Readings

Participants within the knowledge application learning group produced a common theme of continuously mentioning different items of clarity from the background readings. This group was given the opportunity to read the background content of how gliders function, key terms, formulas, and other background knowledge before constructing their glider simulation.

Throughout the focus group interview, many participants referred back to many areas of their readings stating it helped to clarify or provided new information to them that helped throughout their designing process:

...yes, I knew it in a general sense. But with the readings it clarified it, like all the formulas basically. Where the best places for the weight, for the distances between the wings and stuff, that was helpful. It was something I didn't know at all.

I opened up the wing ratio of the area and stuff like that. I looked at the static formula and position of the wings. I looked at the position and the center of mass and tried to keep with that generally in my head while I was making my glider.

I kept that knowledge content of the formulas. Where the small ranges, where it should be – I went back to that a lot.

Trial and Error Learning Group:

D. Changes and Patterns

Throughout the focus interview with the participants of the trial and error learning group a theme emerged of a constant state of change or finding patterns. Within the interview there were many instances of participants mentioning having to completely change their thought process or idea. They discussed that due to a lack of knowledge, they had to change their design numerous times in order to find a pattern to follow to create a successful glider.

Participants referenced guessing and finding patterns to help create an effective design:

I feel like I was just guessing in the dark. Yea, it was still guess and check.

Well at first I was just guessing to see what would make it stay in the air for longer than a second. But once I got it to stay in the air for longer than a second, then I started to figure out, oh if I change this then it will stay up a little bit longer or won't nose dive. So then I kind of making decisions.

...paying attention to the documentation, because at first I just made a glider and it was in spec but it sucked. So I actually paid attention to what each element actually did for the flight performance and that's when it started flying.

Summary

This chapter presented the demographics data on the participants, presented mean and gain scores, tested the four research hypotheses with the results, and presented the focus group themes and analyses. Two important items revealed through the demographics data were the lack of previous knowledge for both simulation software and gliders. This was important for the study to help keep out previous knowledge biases and maintain consistency. When looking at the quantitative data and results hypotheses one, two, and four were all

supported from the data analysis, while hypothesis three was not supported. These results gave an indication that both groups were gaining knowledge at a similar pace. In addition to the descriptive findings from the quantitative data, information was gained through the qualitative data of the focus interviews. Several themes emerged from using a grounded theory approach, which showed both commonalities and differences between the knowledge application learning group and the trial and error learning group. Figure 4.6, below, gives a summary of the findings of the quantitative hypotheses and qualitative results in a quick view format.

Quantitative Data		Qualitative Data	
Hypothesis 01	Supported Not significant	Common Themes between groups	<ul style="list-style-type: none"> • The use of optimization • Previous choices
Hypothesis 02	Supported Not significant	Theme in Knowledge Application group	<ul style="list-style-type: none"> • Clarity from the readings
Hypothesis 03	Not Supported Not significant	Theme in Trial and Error Group	<ul style="list-style-type: none"> • Change and Patterns
Hypothesis 04	Supported Not significant		

Figure 4.6: Summary of Findings and Results – Quick View

CHAPTER 5: DISCUSSION

Introduction

In this chapter major findings between trial and error learning and knowledge application are discussed. The findings of this study were based on the data collected in the form of a mixed methods research design. Using this form of instrumentation, both the quantitative comparative analyses and the qualitative ground theory approach between trial and error learning and knowledge application learning were explored. This discussion seeks to achieve an interpretation of empirical analysis of the data and compare the results of the research with the literature review of the views of other researchers. The chapter explores lessons learned about the research from the perspective of the researcher. Additionally, this chapter concludes with guidance and suggestions for future studies relating to trial and error learning versus knowledge application learning.

Summary of Findings

There have been many discussions and dismissals of using trial and error learning within educational fields. The discussions on trial and error learning versus knowledge application learning is evident but had not been looked into fully within the field of Technology, Engineering, and Design Education. It is a topic in which the discussions go back and forth to what is a viable and the best way for a student to learn and gather their own information. A person is able to learn by trial and error learning by rejecting choices that are

erroneous, meaning they will not benefit the situation. Seeking out new strategies and ideas allows trial and error to help a person find new knowledge (Young, 2009).

The study followed a mixed methods research design, specifically an explanatory design. Both quantitative and qualitative researches were collected to help explain one another for an interpretation of the entire analysis (Vrkljan, 2009). The main pathway of this study was a quantitative study with a supplemental component of qualitative research added in order to enhance the understanding and explanation of the quantitative component (Morse, 2003). The quantitative data was collected first to address the study's purpose, and then sequentially, qualitative data was collected to help explain the quantitative results (Creswell & Clark, 2011). Once the qualitative data was analyzed it was integrated into the findings of the quantitative data to explain those findings completely and inform the research questions.

This study carried out analyses of data collected from students enrolled in an introductory Technology, Engineering, and Design Education course, TDE 131 – Technology through Engineering and Design1. One section of this course was offered in the spring semester of 2015, from which the study was completed in. Flight times and iteration counts were used to gather quantitative data from the complete population of all 23 students of the course. Of the students, 65% were male and 35% were female. The students were made up of a majority of Education majors (78.4%) with a small amount of Engineering majors (8.6) and a mixture of other majors (13.0%).

One of the biggest challenges in technology education with virtual simulations is the battle between students learning a material well enough to obtain the knowledge for knowledge application learning. Many times, since students know they are not wasting the

resources, they will approach a virtual simulation with a trial and error learning approach rather than the full knowledge application learning approach. The literature review noted several pros and cons related to trial and error learning and the reliability of this type of learning within different environments. As such, the purpose of this mixed methods study was not to document more positives and negatives but to expand upon this knowledge to look into if trial and error learning is an effective, practical, and efficient learning type within a Technology, Engineering, and Design Education classroom at the post-secondary level.

The study and the results helped to prove trial and error learning is an effective teaching tool by showing teachers that students are able to learn and gain similar information through different learning models. Knowledge application is the standard teaching method, and will continue to be, however, this study aided in the learning that there are other methods in which students can gain knowledge as well. Trial and error learning helps students to put a different type of real world spin in their learning and helps the student to adapt and hone in on problem solving skills that other teaching and learning models might not explore. This model allowed the researcher to not only observe the statistical findings, but also, understand the thought process behind the designing, problem solving, and thinking of the participants.

Research Questions and Summary of the Findings

Within this study, two research questions were addressed. The first research questions was: Is there a significant difference between knowledge application and trial-and-error learning in a classroom for introductory Technology, Engineering, and Design

Education students at North Carolina State University? This research questions was answered using quantitative data and descriptive statistics to support the findings.

The following research hypotheses guided the study, sample selection, testing instrumentation, data collection, and the analysis of the data:

H01: There will be no significant difference in the flight duration gain scores between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

Both the knowledge application learning group and the trial and error learning group had a raise in flight duration between the beginning flight duration and the final flight durations, when looking within the contents of each group. However, even though each group jumped in mean differences individually, when looking as the gain scores between or across the groups, there was no significant difference in the gain scores. The knowledge application learning group had a mean difference of 3.55, while the trial and error learning group had a mean difference of 4.64. When analyzing the gain scores across the groups the p -value=0.295, stating there is not a significant relationship. The findings supported Research Hypothesis 01.

H02: There will be no significant difference in the number of iterations created between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

The mean of the number of iterations created for the knowledge application learning group (10.46) was similar to the mean of the number of iterations created for the trial and error learning group (13.68). The p -value for the difference of iterations across the

knowledge application learning group and the trial and error learning group was $p = 0.255$. This showed the difference in the number of iterations created across the knowledge application learning group and the trial and error learning group was not significant. The findings supported Research Hypothesis 02.

H03: There will be a significant difference for the beginning flight duration score between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

When calculating the scores for the beginning flight duration for the knowledge application learning group and the trial and error learning group, the scores were comparable. The mean flight duration for the knowledge application learning group (13.17) and the mean flight duration for the trial and error learning group (10.73) were not significantly different. The p-value for the beginning flight durations across the knowledge application learning group and the trial and error learning group was $p = 0.361$, meaning it was not significant. The findings did not support Research Hypothesis 03.

H04: There will be no significant difference for the final flight duration score between the knowledge application learning group and the trial-and-error learning group, at the $p=0.05$ level.

The scores of the final flight durations for the knowledge application learning group and the trial and error learning group were, also, not significantly different. The knowledge application learning group (11.96) and the trial and error learning group (12.05) had similar mean final flight durations. The p-value for the final flight durations across the knowledge

application learning group and the trial and error learning group was $p = 0.975$, meaning it was not significant. The findings supported Research Hypothesis 04.

The second research question used for the study was: How do university students, using either knowledge application learning or trial-and-error learning, make choices when given a virtual glider simulation assignment in an introductory Technology, Engineering, and Design Education classroom? This research question was answered using qualitative data and inferential statistics through a grounded theory approach.

Data was gathered from focus group interviews with each learning group. These interviews were audio recorded, transcribed, and coded to find common themes. From the data analysis, four themes surfaced. Two of the themes, the use of optimization and previous choices, emerged mutually from both learning groups. While, one theme, clarification from readings, emerged only from the knowledge application learning group and one theme, changes and patterns, emerged only from the trial and error learning group.

Although the use of optimization was a common theme for both groups, within the group interviews, it was very evident that the two different learning groups used the optimization tool differently. The optimization tool is a read-out within the Whitebox Learning software that shows the balance of variables within the glider. In the knowledge application learning group, the students already knew the terms of the glider and understood the different components or variables, such as drag, pitch, and yaw. Due to this background knowledge, the knowledge application learning students expressed a use of the optimization tool as more of a “checking tool” to help improve their flight times. The students within this

group were able to create their virtual glider, and check the optimization tool to see exactly what parts of the glider needed improvements from the read-out. At that point, they were able to use the knowledge gained from the readings to apply the improvements to the correct parts of the glider to make a more optimal design. However, students within the trial and error learning group, although they also expressed a beneficial use of the optimization tool, used it in a different capacity. The participants within this group did not have the background knowledge of what each component meant from the optimization read-outs. They had to slowly tweak their gliders and figure out through a trial and error process which part of the glider had a direct connection to which component of the optimization. Although, the connection between the glider and optimization tool for the knowledge application group started stronger, the trial and error learning group showed a gradual build of knowledge and connection in order to have the same final results as the knowledge application learning group.

Conclusions and Discussion

The purpose of the study was to determine the difference between knowledge application and trial and error learning within a Technology, Engineering, and Design Education classroom. Within the study, students were to create a glider simulation. Some participants were given background knowledge prior to creating their design, while others were not. The purpose of this was to check if the participants who did not receive the background knowledge could gain the same amount of knowledge and do as well when creating their glider designs as the students that received the background information. It was

a study investigating if trial and error learning is a viable learning source to use in the classroom or not.

The results of both groups were comparable throughout much of the data collecting process. Both the knowledge application learning group and the trial and error learning group began their glider iterations with low flight duration times. There was no significance in the difference between the knowledge application learning group beginning flight time and the trial and error learning group beginning flight time. As they progressed throughout the glider design project, both learning groups corrected faults using the optimization tool in the simulation program and knowledge they gained from previous design attempts. The knowledge application learning group was able use clarification from the background readings to help increase their design and flight times, while the trial and error learning group was able to use a “guess-and-check” method which helped them to create many changes and recognize patterns to help increase their design and flight times. Since both groups had different tactics they were able to use to help with their glider designs, there was no significant difference in the number of iterations created between the two learning groups. The knowledge application learning group and the trial and error learning group both ended with increased flight duration times from when they started, indicating a gain in knowledge from the beginning of the assignment to the end. However, also indicating no significant difference between the groups when looking at final flight duration or gain scores.

One note of importance, however, is a difference in information learned through the two different learning groups. Within the knowledge application learning group, part of the clarification through readings included formulas connected with the different aspects of the

glider and the success of their virtual prototypes. The participants in this group used those formulas to help improve their glider iterations. The trial and error learning group, while still gaining knowledge, was unable to gain the knowledge of the math and science formulas. This group was never exposed to the formulas or other science and math connections, causing a gap in the participants learning which could have a negative effect in the future.

Although no results were found significant, the gain scores increased for both groups, demonstrating that both groups did learn and take away content knowledge from the activity. Both of the learning treatments were equally effective for the students participating in the study when looking at each group individually. The trial and error learning group had a gain score of 4.64 and the knowledge application learning group had a gain score of 3.55. By examining the methods together and focusing on the final flight durations, there is only a mild difference in the scores causing a conclusion that both styles of learning are effective and an efficient way of learning within the Technology, Engineering, and Design Education classroom at the post-secondary level. This can be backed up by the rational choice theory. The rational choice theory explores and explains the rationality of a person's choice will always be in the best interest of the problem. A person will always make the most logical decision that will provide them with the greatest benefit for their own self-interest by calculating the cost and benefits prior to deciding (Scott, 2000). The rational choice theory is predicated on the fact that individuals will actively and efficiently pursue their goals. Individuals may or may not have information regarding their topic, but based on their current understanding of the goal and the alternatives, they will select the course of action with the greatest promise of success (Green & Fox, 2007). When looking at the data, the trial and

error learning group began with a lower beginning flight duration mean of 2.11, while the knowledge application group started with a 3.12. However, both groups ended with a final flight duration of almost identical with the trial and error learning group obtaining a mean of 6.76 and the knowledge application learning group obtaining a mean of 6.67. As a result from this data collection and analysis, it can be said that trial and error learning has the possibility to be a viable and efficient learning style, just as knowledge application, however, further research is needed to fully understand the learning process and learning effect. After looking at the quantitative data, to fully understand if trial and error learning was present, it was imperative to know the thought process and why the participants made the selections they did. A mixed methods approach with grounded theory in the qualitative portion of the study was used. When using mixed methods, a researcher is able to more deeply and fully understand the information gained from the study by using an integration of both quantitative and qualitative research (Johnson, Onwuegbuzie, & Turner, 2007). By collecting both sets of data, the researcher was able to explain both the quantitative results and the qualitative results and their integration together for a more complete comprehensive study of the phenomena (Vrkljan, 2009).

Figures 5.1 through 5.4 display the engineering results given by the program Whitebox Learning. Additionally, each scatterplot includes a line of best fit for each set of graphed data. The scatterplots display the learning curves for four of the participants within the study. Two of the participants are from the knowledge application learning group (Figures 5.1 and 5.2) and two of the participants are from the trial and error learning group (Figures 5.3 and 5.4). Each student completed different amount of iterations, yet it is visible

to see the learning curves in the knowledge application learning group students were marginally smoother than the learning curves of the students in the trial and error learning group. While all four participants showed tremendous growth with their flight duration times from beginning to end, the trial and error learning group students showed much more variability within their iterations. The lines of best fit within each scatterplot help to show and prove the difference in variability between the two groups and their different tactics. Both knowledge application learning group examples, while one was closer to the trend line, follow closely to the line of best fit, whereas, the two examples from the trial and error learning group jump above and below the trend line drastically. The trial and error learning group's flight times bounced around until they were able to realize and learn from their previous attempts of what worked, was optimal and what was not.

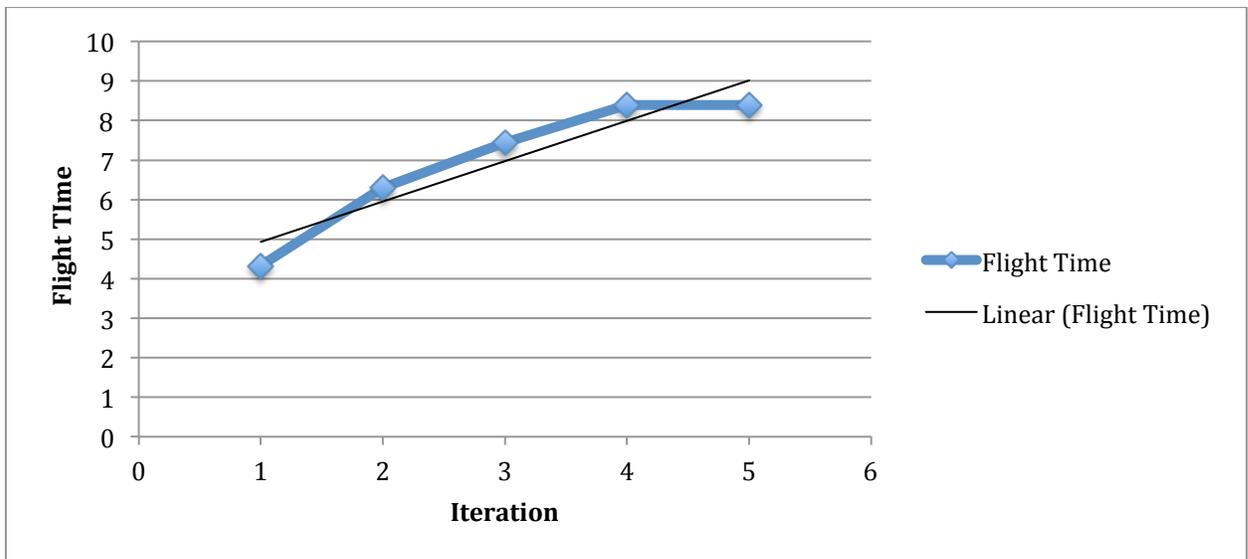


Figure 5.1: Knowledge Application Student Example 1: Engineering Results

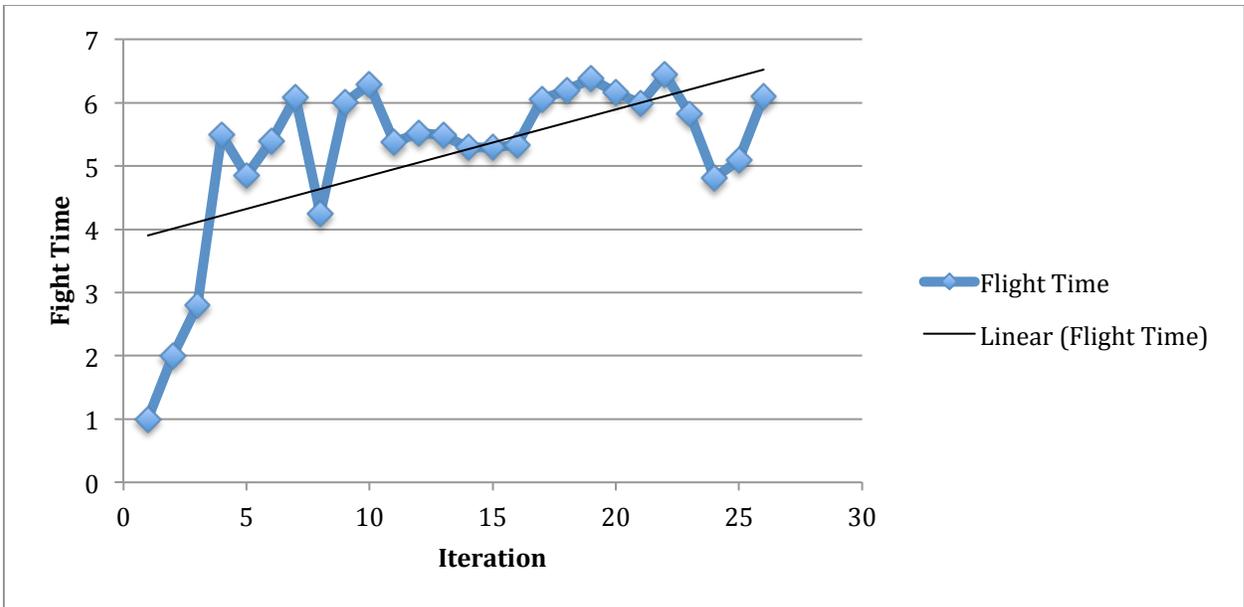


Figure 5.2: Knowledge Application Student Example 2: Engineering Results

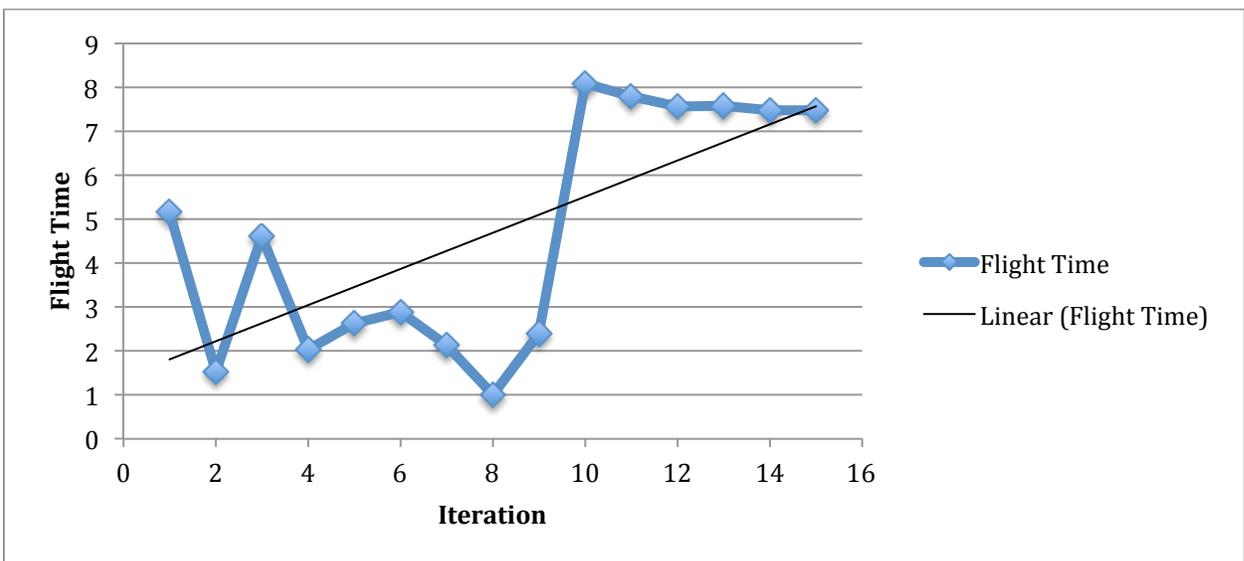


Figure 5.3: Trial and Error Student Example 1: Engineering Results

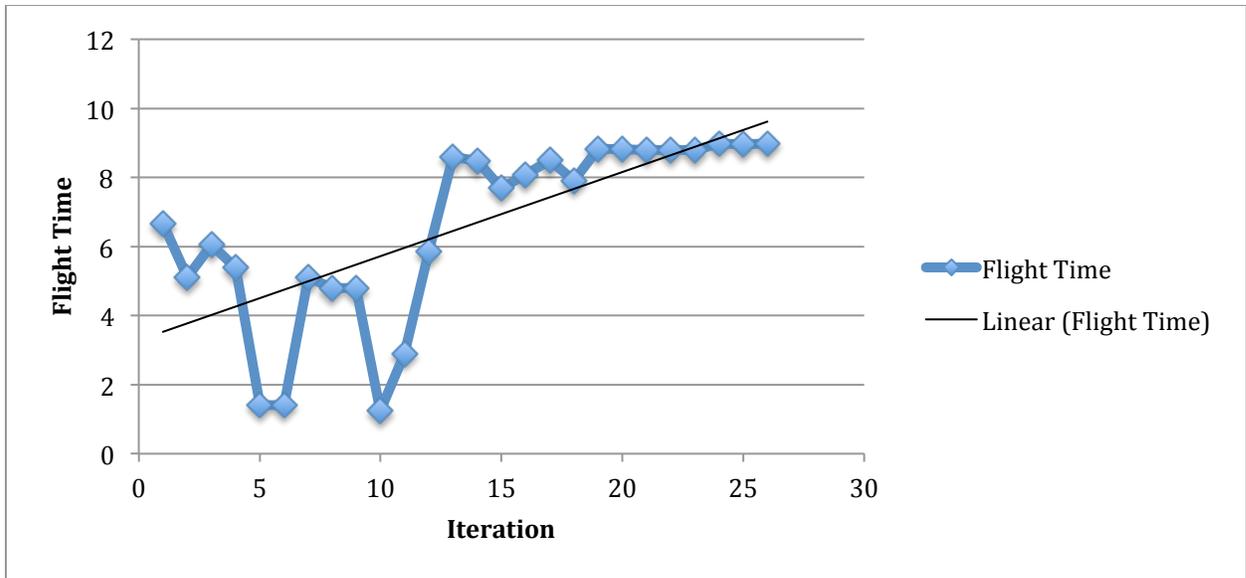


Figure 5.4: Trial and Error Student Example 2: Engineering Results

This study is important because it provides new information on the trial and error learning process and how trial and error learning can be used in a classroom setting within the technology education field. The conclusions of this study prove that trial and error learning has the possibility to be as useful as knowledge application learning. While knowledge application learning is a main learning style that provides students with all of the information they need prior to a problem solving assignment, trial and error learning demonstrates a certain level of feasibility. When a student enters the real world, facts are not always given prior to the problem needing to be solved. Trial and error learning gives a small glimpse into this reality while still maintaining an educational outlook at solving a problem.

Recommendations for Further Research

This study examined the effectiveness of both knowledge application learning and trial and error learning within a Technology, Engineering, and Design Education course at the post-secondary level. The conclusions reached by the researcher suggest several areas of further research.

1. A larger sample with simple random sampling should be examined to confirm the results revealed in this study.
2. A larger sample that included more females should be examined to look into any gender differences that could possibly occur within the study. Gender differences that could be looked at are their designing process when building simulations and their design thinking when problem solving and creating prototypes.
3. The study needs to be replicated at other post-secondary institutions with similar populations to allow generalizations to be made about the data and analyses of the study.
4. A further study needs to examine trial and error learning individually. The study would focus specifically on each iteration made, the amount of time spent on it, and the planning process for it. It would be a more detailed investigation into the workings of trial and error learning and the outcomes of the knowledge base a student builds from this type of learning.
5. A study that looks at the point of convergence for each type of learning. Merriam-Webster (2016) defines convergence as the act of moving towards union or uniformity. Thus defining point of convergence within the parameters of a study to

be the point when two different phenomena, knowledge application and trial and error learning, approach and meet along a point or line causing union or uniformity. The study would focus on where the level of learning meets and becomes unanimous between the two different types of learning, knowledge application and trial and error learning. For example, a specific flight time would be chosen, as the point of convergence in order to maintain reliability and both types of learning would be analyzed according to the data graphs given on the student's iterations and progression to the specified flight duration. Data would be collected on all iterations made by the participants and their progress. The progress of each student towards this flight time would be documented and combined to form a larger generalization for each individual group of knowledge application and trial and error learning. This study would give a more in depth insight to the viability of trial and error learning versus knowledge application learning within a classroom.

6. A study relating specifically to the iterations created while still viewing the study through two lenses of knowledge application learning and trial and error learning. It would look at all iterations, meaning investigating the number of valid (or in specification) iterations versus the number of invalid (or out of specification) iterations between groups. The study would have the main question of: Does having the background knowledge allow for less invalid iterations?
7. A study relating to the theme that emerged from the knowledge application learning focus group interview, clarity from the readings. This theme showed the participants within this group went back to the readings in order to clarify different items, such as

the formulas used throughout the building process of the simulation and how different elements will affect their glider. A future study would look at how this affected the trial and error learning group. This group never had access to any formulas, so while they seemed to be on a similar learning curve to the knowledge application learning group they still ended the experiment with different knowledge learned. The study would look into what math and science components are missing for the trial and error learning group, which would help to decipher if the simulation is reinforcing the content or vice versa within each group.

8. A study relating to the optimization tool within the simulation software and how it impacts a student's learning. Through this study, it was shown how imperative the optimization tool became to both the knowledge application learning group and the trial and error learning group. However, this tool was a “crutch” that the Whitebox Learning software created as a quick view into problem areas within the glider simulation. This tool does not explore or discuss all avenues of issues or optimization when it comes to designing a glider. Further research would be a study of a similar outline but without the use of the optimization tool. It would examine if the results stay the same or would it show other flaws or advantages through the learning processes.

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APPENDICES

APPENDIX A: INFORMED CONSENT FORM

North Carolina State University INFORMED CONSENT FORM for RESEARCH

What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in this study is voluntary. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?

The purpose of this study is to examine different learning sources within a glider activity in a Technology, Engineering, & Design Education class.

What will happen if you take part in the study?

The research will take place within normal class time. It will take four class durations, the first two being for the readings, quiz assignments, and construction of your glider, and the last two classes being for a follow interview to review the reasoning behind your decision making throughout your glider construction. These activities are required course assignments, regardless of the study. If you choose to participate in the study, your data collected will become part of the data used within the study.

Risks

There are no potential risks associated with the proposed procedures.

Benefits

The benefit of this study is to allow instructors to see the effectiveness of both knowledge application and trial and error learning for students within Technology, Engineering, and Design Education introductory courses.

Confidentiality

The information in the study records will be kept confidential to the full extent allowed by law. Data will be stored securely in a locked office at NCSU and/or on a password protected external hard drive. No reference will be made in oral or written reports, which could link you to the study. Data in the reports will only be looked at in aggregate terms and confidentiality of the students will not be broken.

Compensation

There is no compensation for participating in this study.

What if you are a NCSU student?

Participation in this study is not a course requirement and your participation or lack thereof, will not affect your class standing or grades at NC State.

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the researcher, Marissa Franzen, at mmsloan@ncsu.edu, or 919-414-5248.

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator, Box 7514, NCSU Campus (919/515-4514).

Consent To Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature _____ **Date** _____
Investigator's signature _____ **Date** _____

**APPENDIX B: GLIDERS PROJECT DESIGN SHEET –
KNOWLEDGE APPLICATION LEARNING GROUP**



Gliders

Project Design Brief

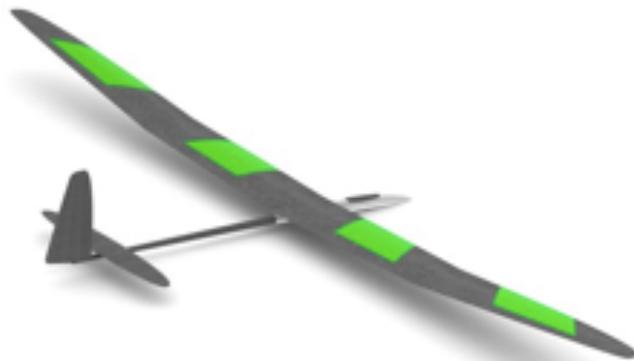


For the next few class periods, you will be learning, exploring, and virtually simulating a glider.

Directions:

1. Complete Demographic Survey
2. Read thoroughly through ALL of the glider information. Complete the questions/quizzes as they arise in the readings. It is important to actually work through the mini-quizzes as they occur and not skip through them. As the tutorials arise, make sure to complete each one to fully understand the building process.
3. Once you have completed all of the background content and feel comfortable with the program, begin building your virtual glider simulation. Everyone will design a glider, and then test them using the software against other students in the class.
4. Participate in a group discussion on your process and reasoning for creating your simulation glider.

Schedule: You will have two class durations (4 hours) to complete steps 1-3. We will complete step 4 separately.



**APPENDIX C: GLIDERS PROJECT DESIGN SHEET –
TRIAL AND ERROR LEARNING GROUP**



Gliders

Project Design Brief

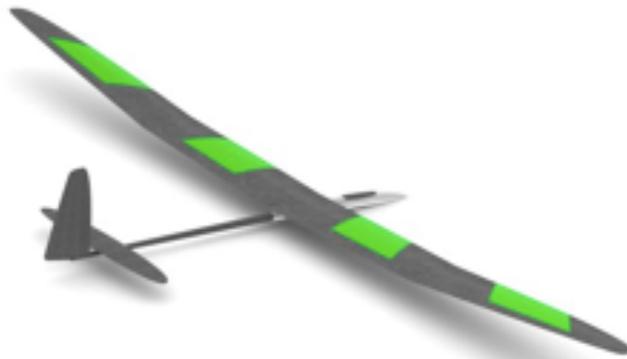


For the next few class periods, you will be learning, exploring, and virtually simulating a glider.

Directions:

1. Complete Demographic Survey
2. Read thoroughly through ALL of the glider tutorials. As you are reading, be sure to complete the steps of the tutorial in the simulation software to fully understand each step.
3. Once you have completed all of the tutorials and feel comfortable with the program, begin building your virtual glider simulation. Everyone will design a glider, and then test them using the software against other students in the class.
4. Participate in a group discussion on your process and reasoning for creating your simulation glider.

Schedule: You will have two class durations (4 hours) to complete steps 1-3. We will complete step 4 separately.



APPENDIX D: DEMOGRAPHIC SURVEY

Demographic Survey

1. Are you male or female?

Female

Male

2. What is your age?

17 or younger

18-20

21-29

30 or over

3. What is your current educational class status?

Freshman

Sophomore

Junior

Senior

Senior +

4. What is your current Major?

5. Have you ever transferred majors? If so, what was your previous major(s)?

6. Do you have any previous knowledge on or experience with the following:

	None	I have played around a little with them	Yes, A lot of previous knowledge/experience
Simulation Software (besides what you have learned in class this semester)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gliders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

APPENDIX E: FOCUS INTERVIEW TRANSCRIPTION – KNOWLEDGE APPLICATION LEARNING GROUP

Control Group (Knowledge Application Group) – Interview Transcription

Leader: Okay, so while you were creating your glider simulations what factors informed your design decisions as it relates to creating your glider simulations. So, what that means, in other words, as you were creating your simulation what lead you to make the design decisions you did as your were creating it?

Participant: Weight dispersal. Distributing the weight properly and changing up where the wings are and where their at. It's hard to design the glider if you don't have the thickness for the wings and making it in spec and changing the weight.

Participant 2: Yes, I was focused on the center of mass and where the weight is according to the wing. Yea, so I would have that one constantly so that I could see what changes we did to it

Participant 3: I had the optimization graph next to it so I could make sure the drag was minimal and everything was as optimal. I would just tweak everything, change the shape of the wings and saw how that affected everything.

Leader: So what did the optimization graph actually show you, what was in it that showed you was optimal or not?

Participants together: The drag, yaw, pitch, and lift

Leader: Okay and it just showed you

Participant: It shows what was okay, better, best. It had bars.

Leader: Okay, so all those elements that you guys just mentioned, did you know what those all were prior to this unit?

Participant: Yes. No.

Leader: Did you learn them while you were doing your background readings or you already had that background knowledge?

Participant 2: Existing knowledge.

Participant 5: From the readings.

Participant: Yes, the readings too.

Leader: But once you read it in the readings, did it make sense? Did you understand it enough that it was applicable to what you were creating?

Participant 5: Generally.

Participant 2: It clarified for me.

Participant 3: Yes, yes, I knew it in a general sense. But with the readings it clarified it, like all the formulas basically. Where the best places for the weight, for the distances between the wings and stuff, that was helpful. It was something I didn't know at all.

Leader: So did anyone have a large jumping your performance, like your flight time as you were trying out your different designs. Did you have a large jump or was it gradual?

Participant 6: Mine jumped from 1 second to 7 seconds after I found the optimized tool.

Leader: So that really helped

Participant 6: Yea

Participant 2: The first design I did was pretty low performance. It was based off live action, not actual gliders. And, um, after I kind of started looking at some of the top 10s I started to make some significant design changes. And after that then the optimization started to help me with the fine tuning.

Participant 3: Yea, I started out with kind of the same thing. Past experiences for me, like paper airplanes, which flew better. Often with a broader wing were the ones they design for gliders. They weren't fast but they floated for a long time.

Leader: So then how were your design solutions influenced by your previous choices? As you were making your glider, your different iterations, did you use what worked and didn't work and try to fix that. Or did you try to fix everything as a whole. Were you trying to fix one thing at a time or everything all at once?

Participant 6: I would try to fix one thing at a time. Once I would change something, I would test it to see if it worked better or worse. If it did work better than I would keep it and then fix everything to make it better. And if it didn't work then change that and see how it worked the next time.

Participant 3: Yea, I wouldfor me it's going to affect a lot so things, so I kind of was focused on one piece at a time but also how it dramatically affected something else. If it

didn't effect it that bad or at all then I just kind of did it one step at a time, one aspect at a time.

Participant 2: I would just keep the different versions. Because when I was trying to tweak one thing I would go through a couple versions and I would realize the first version I had, 3 iterations back was more effective. I would go back to that and change that and see if it could improve from there. So, keeping and having a log of how each one performed

Leader: Okay, so you kept a log. Did most of you keep a log? Or did you do a blank slate every time?

Participant 2: I kept a log

Leader: This touches base on what I asked before, but did you see a pattern in your flight time? Did it gradually grow or did it go up and down with the flight times depending on what you did? Or was there any sort of pattern at all?

Participant 3: It just sort of got better and better. The more you tweaked it.

Leader: So you did not have a drop and then go back up?

Participant 6: I think the only thing I had was mine kept going out of speculations. If I wasn't looking at the because there is no way to look at that in the simulator. You have to go back to the outputs. So I would pick something and test it, then all of the sudden I would be out of specs.

Leader: Touching base with what we did a second ago, with the previous choices, your previous choices didn't really influence you. Did you base your new design decisions off your previous choices of what you saw or did you go back towards your knowledge content of what you read to make it better?

Participant 3: I kept that knowledge content of the formulas. Where the small ranges, where it should be – I went back to that a lot.

Leader: So did anybody else touch base or thought about the actual content that you read instead of just guessing and checking?

Participant 2: I opened up the wing ratio of the area and stuff like that. I looked at the static formula and position of the wings. I looked at the position and the center of mass and tried to keep with that generally in my head while I was making my glider.

Leader: Okay perfect.

APPENDIX F: FOCUS INTERVIEW TRANSCRIPTION – TRIAL AND ERROR LEARNING GROUP

Trial and Error Learning Group – Interview Transcription

Leader: What factors informed your design decisions as it relates to creating your glider simulations? So in other words, as you were making your design decisions, what lead you to make those decisions?

Participant 1: I used the optimization tool, so I just kept changing stuff until it was at the optimal levels.

Leader: Okay, anyone else?

Participant 2: That was pretty much how I did it too.

Participant 3: Same here.

Participant 2: Changed around values until it was all optimal and at the best.

Participant 4: And I used the outputs to make sure it was in spec.

Leader: Okay. Was there a large jump in anyone's performance? In your flight time? If so, what lead to that jump?

Participant 3: Paying attention to the documentation, because at first I just made a glider and it was in spec but it sucked. So I actually paid attention to what each element actually did for the flight performance and that when it started flying.

Leader: Okay, so what did you change around? What factors did you actually change around that you realized that you didn't know before?

Participant 3: The factors that were on the paper, I can't remember. The pitch, yaw, I can't remember the other ones.

Leader: So did you guys know what all those meant prior to this?

All participants: No. Yes. Most of them.

Leader: Okay, so half and half?

Participant 4: The key thing for me was watching the center of gravity. The center of gravity changed a lot of how well it flew.

Leader: Okay, so then, how were your design solutions influenced by your previous choices? You guys mentioned the optimization but besides optimization, what was your rationality throughout the whole process?

Participant 5: I would only change one thing at a time, and if that didn't work then I would change it back and I would change something else.

Leader: Did most people do one at a time or did you guys all do a lot?

Participant 4: I just kind of did some to see what changes were needed and did it all at once.

Participant 7: I did that too. If I still wasn't getting the results that I wanted then I would end up changing my whole design instead of going through each one.

Leader: Okay, so you made completely new design each time? Did you save each design each time or did you start brand new?

Participant 7: I know I saved one of them to compare it with my new design and then my new design ended up winning so I did not have to go back to the other one. But I did that a few times.

Leader: Did you guys see a pattern in your flight times, as you were making it from the very beginning to the very end. Was there a pattern of the flight times, or did that kind of just fluctuate?

Participant 4: I got 1 second

Participant 1: Yea, I was stuck at a second for a long time

Leader: But then eventually it got higher?

Participant 4: I was stuck at one second but the tenth time I got 3.5 seconds. Then stuck at a second for forever then 4.5 seconds.

Participant 2: Mine was kind of just all over the place.

Leader: Up and down, depending on what you changed?

Participant 2: Yea

Leader: So then what made you actually stop, stop creating things?

Participant 5: When I started beating everybody else

Participant 3: I exceeded 4 seconds. I was then complacent.

Participant 1: No matter what I did, the values just wouldn't change

Leader: We kind of already touched on this. So with your past choices, did you change things because of what your flight or glider was doing the previous time or were you just messing around and changing things around to see what would happen? Was it based off your previous flight or was it based off just anything.

All participants: I based it off both

Participant 2: I based it off both but more mainly off the previous one. You have visible data that you can change; you can see what needs to be changed.

Leader: and were you able to change specific parts, the wings width or whatever depending on what that flight was. Or did you kind of just have to guess to what made that happen.

Participant 2: Well at first I was just guessing to see what would make it stay in the air for longer than a second. But once I got it to stay in the air for longer than a second, then I started to figure out oh if I change this then it will stay up a little bit longer or wont nose dive. So then I kind of making decisions.

leader: By the end of the whole unit or making the glider, did you guys feel like you had a good grasp on your glider or were you still just in the "it worked but you have no idea why." Did you know why it was working or was it just still guessing.

Many participants: I feel like I was just guessing in the dark. Yea, it was still guess and check.

Participant 1; I had more of an idea.

Participant 3: I don't remember specifics, like I can't tell you the exact times. But I can tell you if you make this a little longer it will do this if you ask.

Leader: So, as a whole do you guys understand the concepts of the glider. Some of you already said you knew the key words like the pitch and the yaw, and all that. But if you had to go back and explain to somebody else, would you be able to explain the different parts of it?

Different participants: No. Yes.

Leader: Do you have the comprehension of it?

Different participants: Depending. A little.

Leader: A little bit? Okay.