ABSTRACT

EFFECTS OF SIMULATION FEEDBACKS ON COMPUTER ENGINEERING STUDENTS' KNOWLEDGE

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Feedback is an essential element for improving student performance in simulation-based training, as it guides and refines learning through scaffolding. Various studies have shown that students' learning is enhanced when feedback is provided with personalized tutoring that offers specific guidance and adapts feedback to the learner in a one-to-one environment. Therefore, emulating these adaptive aspects of human tutoring in simulation provides an effective methodology to train individuals.

This study investigates the effectiveness of automating different types of feedback techniques such as knowledge-of-correct-response (KCR) and answer-until-correct (AUC) in software simulation for learning basic information technology concepts. For the purpose of comparison, techniques like simulation with zero or no feedback (NFB) and traditional hands-on (HON) learning environments were also examined.

To test the hypotheses, 80 participants were equally, but randomly, assigned to four lab groups: HON, NFB, KCR, and AUC. After attending a short lecture on the topic of Local Area Network (LAN) cabling system and taking a pretest, participants performed the lab

experiment in one of the four assigned learning environments. After completing the lab work, each participant took the posttest. Finally, the pretest and posttest scores were analyzed to measure the learning outcome.

The findings based on quantitative analyses verified that the simulation-based instructional strategies are at least as effective as hands-on teaching methodologies for the purpose of learning of IT concepts. The results obtained also verified the earlier studies, suggesting that AUC was an optimum form of simulation feedback. The KCR feedback effectiveness, on the other hand, cannot be validated; hence, recommendations are made for conducting future research. In summary, the results obtained from this study have positive implications for the implementation of feedback in computer-based simulated training.

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CHAPTER 1

INTRODUCTION

The continuing growth on the technological front has been challenging all of us with the new ways to convey information. From the early days of radio to the new age of the Internet, the underlying purpose remains the same. The key components to the success of every new instructional or communication technology are the dissemination of information, its timeliness, and its effectiveness. It is no secret that today's Internet and associated technologies are encouraging evolutionary learning techniques both in academia and the corporate world. From a corporation website to a college online system, new ways are being implemented daily to formulate information and enhance delivery mechanisms to improve effectiveness. The Internet, with its distributive architecture, has provided the power to combine a series of discrete, unlinked, and unmeasured activities into an enterprise-wide process of continuous learning that directly links business goals and individual outcomes (McCrea, Gay, & Bacon, 2000). Our economic, social, and technological forces today are pushing all of us to become more productive in every walk of life, and learning is no exception.

One of the learning tools that have become more prevalent in the field of instructional technology is simulation. The focus of this chapter is to understand software simulation and its role in technology-based curricula, especially in the area of information technology (IT) training such as computer networking and infrastructure.

Simulation

Educational institutions are continuously being challenged to offer flexible learning platforms. According to Bell, Kanar, and Kozlowski (2008), "A number of emerging challenges, such as economic pressure, globalization, work-life issues, have combined to create a business environment that demands innovative flexible training solutions" (p. 6). From distance education to online learning and from portable gears to simulations, are all parts of the same effort, i.e., to establish flexible learning environment. Today, most undergraduate technical education and/or training such as electronic circuit analysis, microcomputers circuits, information technology management, etc. are being offered in a traditional hands-on lab environment, but recent advances in technology have positioned simulations as a powerful tool for creating more realistic learning platforms (Chen, 2003). Therefore, the challenge of completing required hands-on activities in science and engineering curricula can be realistically achieved through the use of simulations. According to Bell et al. (2008), "One of the major benefits of online/offline simulation is its flexibility, as simulations can offer learning opportunities that can take place almost anytime anywhere without the additional cost of traditional lab equipment and instructors" (p. 4). According to Sancristobal, Castro, Martin, and Tawkif (2011), when the real instruments are very expensive, it is a good solution to use simulation programs. The use of simulation not only reinforces the possibility of flexible learning, it may also prove to be a very good business model, as stated by Gillet, Ngoc and Rekik (2005), "The motivation for flexible education at the level of academic institutions is mainly a question of competitiveness in attracting students and in positioning as centers of excellence" (p. 696).

A student working in a traditional lab environment also has the disadvantage of being frustrated in terms of his/her classmates' interference and the noise intensity, which can potentially prohibit students from immersing completely. Simulations, on the other hand, have the ability to create customized micro or synthetic worlds that capture trainees' attention and absorb them fully (Schiflett, Elliot, Salas, & Coovert, 2004), and such immersion can enhance learners' feeling of presence, or the perception of actually being in a particular environment (Steele-Johnson & Hyde, 1997). Such real-world settings can in turn contribute to prompting psychological processes that are responsible for improving performance characteristics (Schiflett).

One of the possible performance characteristics simulations can improve is one's ability for critical thinking. According to Zantow, Knowlton, and Sharp (2005), "The learning environment created by simulations helps developing an understanding of the relationships among different components, integrating information with existing knowledge, and making decisions" (p. 452). Making decisions requires problem-solving skills, and problem-solving practices promote cognitive processes. According to Gokhale (1996), "Simulations help develop higher-order thinking strategies and improve student cognitive abilities employed in the service of recall, problem-solving, and creativity" (p. 44). Leger et al. (2011) reported that simulations involve interaction that allows learners to test problem-solving strategies, experience the consequences of their actions, and adjust their decisions in a safe environment.

Games and social simulations are often used for training and teaching in management science, economics, psychology, sociology, intercultural communication, political science, and military strategy because through simulations students can sharpen their observational skills, decision-making skills, and critical thinking (Howard-Jones & Demetriou, 2009).

Risk taking is another area where simulation outshines traditional lab models. The attractiveness of uncertainty has been well established by psychological experimentation that has shown moderate risk taking heightens motivation (Howard-Jones & Demetriou, 2009). But for the purpose of minimizing potential risks, hands-on experiments performed in traditional labs are usually very controlled and structured. Experimenting with expensive equipment and/or hazardous material in labs, therefore, usually prohibits certain students from being very imaginative and bold in terms of carrying out uncertain procedures. Simulations, on the other hand, can be an effective tool when it comes to encouraging creative, investigative, and risk-taking acts without having any monetary, safety, or social consequences. Leger et al. (2011) reported that by making it safe to fail, learners are able to try and experiment, simulation creates an environment where participants develop a natural inclination to try and discover. According to Clifford and Chou (1991):

> When uncertainty is encountered in more real life contexts, there are potentially more complex effects of context created by the social environment. However when the same tasks are presented as games, students will take greater risks. It may suggest that individuals can be deterred from tackling academic tasks with higher levels of uncertainty due to the implications of failure for social status. (p. 504)

But should we abandon hands-on labs completely? According to Corter, Nickerson, Esche, Chassapis, Im, and Ma (2007), “Results indicate that simulated labs can be at least as effective as traditional hands-on labs in teaching specific course concepts but the order in which different lab formats are experienced may have an effect. Result suggests that scores increase in the second experiment if the first was hands-on” (p.13). Therefore, abandoning hands-on labs entirely, before fully understanding the effects of simulated activities on students' learning, would be an oversight.

Even though there are many advocates of simulations, there are also many opponents who see simulations as potentially harmful to students by depriving them of important learning experiences. It is widely accepted that a student's cognitive style can affect his/her preferences for educational media, presumably including preferences for hands-on versus simulated labs (Corter et al., 2007). It is also clear that students learn not only from equipment, but from interactions with peers and teachers (Ma & Nickerson, 2006). As a matter of fact, students rate educational effectiveness of the traditional lab higher than that of the remote lab or simulation (Corter et al., 2007). Hence it is imperative to continue studying the effects of simulated labs on students' learning especially in the area of cognitive-learning, skill-based learning, and affective knowledge.

As this research focuses on students with no prior knowledge of the subject matter, guided discovery-based multimedia environment is an ideal platform for novice learners because it minimizes extraneous cognitive load. According to Moreno (2004), "When students lack significant prior knowledge, the demands that arise from processing the new information without guidance can be overwhelming and leave students with insufficient capacity for building mental representation of the system to be learned" (p. 110).

One of the key attributes of any guided-discovery learning is scaffolding, which will be the primarily focus of the study. The term scaffolding was introduced to psychology by Wood, Bruner, and Ross (1976). In that first incarnation, scaffolding was used to describe the support given by a more expert individual in one-on-one tutorial interactions. Most recently, it has been used by researchers in the learning sciences when discussing features and functions of learning artifacts, especially those of educational software (Sherin, Reiser, & Edelson, 2004).

Scaffolding enables the learner to achieve goals or accomplish processes normally out of reach (Jackson, Krajcik, & Soloway, 1998). One of the scaffolding techniques is supportive scaffolding. In this type of scaffolding, a learner is guided in terms of what to consider, how to create associations between ideas, and how these associations form a supportive scaffolding structure (Hannafin, 1999; Linton, 2000). According to Cagiltay (2006), supportive scaffolding can be accomplished by several methods and mechanisms, such as coaching comments, providing feedback, and provoking reflection. Packet-Tracer provides scaffolding in the form of corrective feedback. According to Jaehnig and Miller (2007), the types of corrective feedbacks commonly used are:

1. Knowledge-of-Response (KOR), which simply indicates that the learner's response is correct or incorrect.
2. Answer-Until-Correct (AUC), it requires learner's to remain on the same test item until the correct answer is selected.
3. Knowledge-of-correct-response (KCR), which identifies the correct response i.e. it directs the student to the correct response

According to Moreno (2004), "The importance of feedback in promoting learning is inarguable. Previous research indicates that different types of feedback have different influences on performance" (p. 110). Several studies have shown KCR to be superior to KOR, and KOR to be superior to no feedback, but this hierarchy of immediate feedback types is not so well established (Clariana, Ross, & Morrison, 1991). According to Jaehnig and Miller (2007), "Overall AUC feedback appears to be highly effective but further study is warranted" (p. 230). On the other hand, a recent study done by Agina, Kommers, and Steehouder (2011) couldn't validate the superiority of AUC over KCR.

Problem Statement

Feedback has the potential to significantly improve learning and performance outcomes; however, there is a continuing discussion about how and when to deliver feedback (Mason & Bruning, 2001; McLaughlin, Rogers, & Fisk, 2008; Shute, 2008). Narciss (2008) notes that "modern information technologies increase the range of feedback strategies that can be implemented in computer-based learning environments; however, the design and implementation of feedback strategies are very complex tasks that are often based more on intuition than on psychologically sound design principles" (p. 126). Consequently, research must be conducted to empirically attempt to determine the most appropriate ways to use technology to administer feedback in computer learning environments, which may not always align with strategies that are thought to be intuitive.

According to Moreno (2004), "The importance of feedback in promoting learning is inarguable but additional research is needed to determine the effects of structured guidance on other educational areas, methods, and student populations" (p. 102). One way to better understand the effect of simulated activities on students' learning is to expand the research to uncommon educational areas such learning technical concepts related to information technology (IT). Even though for several decades researchers have explored the use of simulation to augment the laboratory experiences in the areas of surgery, physics, chemistry, biology, math, and dental education, there is no significant study that measures the effect of students' learning of IT matters using simulation software such as Packet-Tracer. Therefore, conducting research to realize the effects of simulated lab activities on students' learning of Local Area Network (LAN) design and/or troubleshooting concepts will be a significant step in the area of instructional strategies and design in the field of instructional technology.

Purpose of the Study

The purpose of this quantitative study is to explore the impact of the use of computer simulation's feedback – i.e., knowledge-of-correct-response (KCR) feedback and answer-until-correct (AUC) feedback – on students' declarative knowledge in the area of information technology – i.e., computer networking and Infrastructure. Hence, the proposed research is to study the effects of simulation feedbacks on computer engineering students' declarative knowledge.

Research Questions

Research Question One

The first question that is essential to the research is, "Do pure discovery-based (no feedback) simulated labs improve students' declarative knowledge?" The premise of this research is that the simulated experiments are better than the hands-on laboratory exercise when it comes to understanding basic IT concepts. Therefore, the hypothesis is: The use of simulated experiments in the teaching of IT concepts in CCNA program with no feedback (pure discovery learning environment) will produce improved declarative knowledge (as reflected in the differences between pretest and posttest scores) more than the hands-on activities.

Research Question Two

Another question that is central to the research is, "Do KCR (knowledge-of-correct-response) feedback feature of simulated labs in CCNA program improve students' declarative knowledge in the learning of basic IT concepts? Therefore the hypothesis is: The use of KCR-enabled simulated experiments in the teaching of basic IT concepts in CCNA program will produce improved declarative knowledge (as reflected in the differences between pretest and posttest) more than the hands-on activities.

Research Question Three

The third question that is essential to the research is, "Do AUC (answer-until-correct) feedback feature of simulated labs in CCNA program improve students' declarative knowledge in the learning of basic IT concepts?" Therefore the hypothesis is: The use of AUC-enabled simulated experiments in the teaching of basic IT concepts in CCNA program will produce improved declarative knowledge (as reflected in the differences between pretest and posttest scores) more than the hands-on activities.

Research Question Four

The next researched question is, “Do KCR (knowledge-of-correct-response) feedback feature of simulated labs in CCNA program improve students’ declarative knowledge in the learning of basic IT concepts as compared to no-feedback (pure discovery) based simulation?” Therefore the hypothesis is: The use of KCR-enabled simulated experiments in the teaching of basic IT concepts in CCNA program will produce improved declarative knowledge (as reflected in the differences between pretest and posttest scores) more than the no-feedback simulated environment.

Research Question Five

The last question essential to the research is, “Do AUC (answer-until-correct) feedback feature of simulated labs in CCNA program improve students’ declarative knowledge in the learning of basic IT concepts as compared to no-feedback (pure discovery) based simulation?” Therefore the hypothesis is: The use of AUC-enabled simulated experiments in the teaching of basic IT concepts in CCNA program will produce improved declarative knowledge (as reflected in the differences between pretest and posttest scores) more than the no-feedback simulated environment.”

Significance of the Study

Computer-based simulation programs enable students to “play” interactively with the concepts and applications of computer networking such as bridging, routing, filtering, and monitoring. At every step of the way simulation software instantly provides reliable feedback, helping students to evaluate their design ideas for accuracy, as feedback or knowledge of results is critical to support performance and motivation (Garris, Ahlers, & Driskell, 2002). Simulation software therefore can potentially offer students a practical environment for the purpose of developing and experimenting with numerous computer-network design models. According to Leger et al. (2011), simulations create an environment where participants develop a natural inclination to try and discover; coaches must not be seen as the main knowledge providers. The main idea is to give just enough information so learners can start exploring on their own.

Hands-on experiments, on the other hand, have the disadvantage of mixing design errors with the equipment errors and potentially take away the focus from the activity itself; such distraction factors can limit learners' cognitive engagement, as research suggests that learning improves as the quality of cognitive engagement increases and that greater engagement during learning leads to longer retention of information (Paul, Umbach, & Mattew, 2005).

Most science and engineering educators believe that the hands-on experience of the science laboratory is a necessary supplement to the relatively passive experiences of reading textbooks and listening to lectures that comprise a large part of the student experience in universities. Lave and Wenger (1991) argue that "This belief in the value of hands-on work is backed by theories of instruction such as inquiry learning, anchored instruction, and by basic principles of constructivism" (p. 2). Although the merits of hands-on training in a traditional laboratory environment cannot be denied, it has its own set of challenges. First, the traditional lab models lack the flexibility we need to accommodate 21^{st}-century mobile learners. Second, such facilities are usually designed to offer a limited range of controlled lab activities with no support for creative and "bold" experiments, and third, traditional lab facilities are not easily adaptive in terms of matching individual learning needs (Buchanan, 2001). Simulations, on the other hand, can potentially eradicate such limitations imposed by the traditional lab models.

This research potentially offers many contributions to the literature of instructional technology. First, it will validate the use of simulation as an instructional strategy for teaching complex IT concepts without the support of any hands-on experiments and, second, it will verify if simulation scaffolding features such as AUC and KCR feedbacks can enhance students' learning (declarative knowledge) in the area of information technology.

As an instructor, the use of simulation package for the purpose of teaching Local Area Network (LAN) design and troubleshoot concepts has been a blessing, both in terms of its low cost and flexibility. It is clear that students "playing" with the expensive equipment in the labs such as servers, routers, switches, MUXs, DEMUXs, firewalls, etc. without any proper supervision may become a dicey situation; therefore, access to school laboratories is usually very restrictive. On the other hand, simulations software made available on portable devices such as laptops is providing students the required learning opportunities they need with the added benefit of anytime, anywhere flexible learning.

Theoretical Framework

The multimedia-guided discovery-based learning platform chosen for this study is called Packet-Tracer developed by Cisco Systems. Packet Tracer can be configured to provide learners with corrective feedback in the form of AUC (answer-until-correct) or KCR (knowledge-of-correct-response). It provides AUC and KCR feedbacks in the form of graphics (animation). Graphic or pictorial feedback may be more accommodating and effective in accompanying instructional material that is highly visualized (Lin and Dwyer, 2010), but additional research is needed to verify the learning outcomes. As the research focuses on students with no prior knowledge of the subject matter, a guided discovery-based multimedia environment is an ideal platform for novice learners because it minimizes extraneous cognitive load. According to Moreno (2004), "When students lack significant prior knowledge, the demands that arise from processing the new information without guidance can be overwhelming and leave students with insufficient capacity for building mental representation of the system to be learned" (p. 110).

Discovery learning theory, which is based on constructivism, was the framework to conduct the study. Although constructivism takes many forms, an underlying premise is that learning is an active process in which learners are active sense makers who seek to build coherent and organized knowledge (Mayer, 2004).

In discovery learning, students construct their own knowledge by experimenting with a domain and inferring rules from the results of these experiments (Wouter, Joolingen, & de Jong, 1997). In discovery learning, students are confronted with a question or a problem, and they work mostly in a self-directed manner to complete the task and discover the desired knowledge in the process; in other words, students are left to work out the solution on their own (Bruner, 1961).

The research on discovery learning has evolved from pure discovery learning towards more guided discovery learning characterized by the need to improve learning, according to Mayer (2004).

> Pure discovery – even when it involves lots of hands-on activity and large amounts of group discussion – may fail to promote the first cognitive process, namely, selecting relevant incoming information. In short, when students have too much freedom, they may fail to come into contact with the to-be-learned material. In many ways, guided discovery appears to offer the best method for promoting constructivist learning. (p.17)

Since computer simulation has the capacity to provide learners with an exploratory learning environment, it has been regarded as a powerful tool for discovery learning (Reid, Zhang, & Chen, 2003). The challenge of teaching by guided discovery is to know how much and what kind of guidance to provide (Mayer, 2004), as the simulation based learning environment cannot guarantee effective learning without sufficient support or scaffolding for discovery learning activities (Chen, 2003). The fact that learning facilitated by scaffold produces the best learning effects may result from the reduced workload of the scaffold aid (Chang, Sung & Chen, 2001). According to Obikwelu, Read, and Sim (2012), feedback provides an opportunity to support children's learning of unfamiliar educational content by scaffolding them into successfully solving a problem. Scaffolding can be accomplished by several methods and mechanisms such as coaching comments, providing feedback, and provoking reflection (Cagiltay, 2006). These methods are also known as cognitive tools and can be seen as supporting agents when it comes to computer based learning (Lajoie & Derry, 1993). According to Joolingen (1999),

> In supporting discovery learning, cognitive tools may play an important role. Cognitive tools are the instruments helping the learner to direct the process, or to perform a part of it. It would be fairly easy to see almost all things that support

> learning as a cognitive tool. The kind of support that can be generated includes graphs, animation etc. that can provide the learner with feedback on the learning process. (p. 392)

Many computing environments can function as cognitive tools such as databases, expert systems, multimedia, and hypermedia knowledge bases (Jonassen, 1995), but one of the prime examples of multimedia-based cognitive tool is software-based simulations (Ketterer & Toomey, 1995). Simulations provide feedback in the form of features such as animation, graph, text, etc. to support learning in an interactive environment and increases the range of feedback strategies that can be achieved efficiently (Clariana et al., 1991). However, it is important to note the task-specific nature of the visual representation of feedback produced by a computer simulation, because different presentations lead to different learning outcomes for certain tasks (Rieber et al., 2004). Also, according to Moreno (2004), "In guided discovery environments the cognitive tools may facilitate students' selection, organization, and integration of materials by providing feedback on their choices" (p. 102); nonetheless, further research is needed to provide additional information concerning the roles of interactivity and feedback (Moreno & Valdez, 2005).

Therefore, in my opinion, studying the effects of different feedback types such as KCR and AUC on students' learning of IT tasks in a guided discovery environment is a big step forward in the field of instructional technology, as there is no significant research that has captured this information.

CHAPTER 2

LITERATURE REVIEW

As we know, until the early 1970s, simulations were not part of the instructional design strategies. Instead, these exercises were primarily developed by business, medical education faculty, and sociologists who adapted instructional developments pioneered by the military services (Gredler, 1990). Currently, the increased power and flexibility of computer technology is contributing to renewed interest in games and simulations. This development coincides with the current perspective of effective instruction in which meaningful learning depends on the construction of knowledge by the learner. Games and simulations, which can provide an environment for the learner's construction of new knowledge, have the potential to become a major component of this focus based on their ability to motivate and engage (Galarneau, 2005). Simulations have the potential to develop students' mental models of complex situations as well as their scientific and critical thinking methodologies (Rivers & Vockell, 2006).

The focus of this chapter is to present an overview of the state of literature regarding the effect of various feedbacks in simulated learning environments. The first section of this chapter assesses the use of simulation strictly from the cognitive point of view. The second section explores the use of simulation in various fields such as medical and engineering, and the chapter concludes with a discussion of the findings, their analysis, and how they are applicable to my research area. Hence, the scope of the literature review is twofold: to comprehend all the strengths and weaknesses of feedback types currently being integrated in a simulated learning environment and then to offer a solid support for my research proposal. Therefore, all the studies reviewed in this chapter have been carefully selected due to their scope, comprehensiveness, and applicability to the area of my research interest.

Simulation and Discovery Learning

One of the learning theories which has received special attention in simulation is constructivism. Dewey's claim that children construct their own knowledge through experiences gained by observing, exploring, and performing in the real world has been strong enough for simulation software designers to seriously consider the role of constructivism in their educational products (Mayer, 2004).

As a matter of fact, a study conducted by Tan and Biswas (2007) validates that constructivist-based simulations environments that provide an adequate flow to motivate students and sustain their interest indeed breed better learning. The result of their study clearly demonstrated that the group with simulation did notably superior than those in the nonsimulation environment, as the group using simulation had a better opportunity to construct their own learning experiences with deeper understanding. The discovery learning process offered by the simulation software also helped students to develop scientific inquiry and experimentation skills, and at the same time attempted to correct misconceptions and mistakes that may arise from prior knowledge. Another study conducted by Kim and Jang (2011) also concluded that the experimental group who had simulation-based training in the area of cardio-pulmonary care showed significantly higher knowledge compared with the control group, who had a traditional mode of learning. But despite the enthusiasm for educational simulations in the guided discovery arena, many challenges to the effective design of simulations remain, and one of the most important considerations in a simulation's interface design is how to provide meaningful feedback to the user (Rieber, Tzeng & Tribble, 2004).

In order to stay competitive in the field of technology, one of the desirable goals of engineering education is to promote problem-solving skills, as without such ability, the students will not be fully equipped to face 21st-century challenges in terms of creativity and innovation. Without such skill, innovation takes too long and costs too much (Warsame, Biney, & Morgan, 1995). A study done by Gokhale (1996) has concluded a fascinating result in this regard. The focus of his study was to examine the effectiveness of integrating guided-discovery computer simulation into traditional lecture-lab activities to augment students' problem-solving capacities. It was found that the group using simulation software to do the lab work performed significantly higher than the other group when answering problem-oriented questions, while both groups performed equally well on the drill-and-practice questions. Therefore, it was concluded that the integration of simulation in technology curriculum does help if the educational goal is to transfer and apply the knowledge to real-world problems. A similar study done by Kumar and Sherwood (2007) also concluded that the undergraduate students who acquired knowledge from problem-based simulation software were able to transfer their conceptual understanding of scientific topic of the composition of air more effectively than those who did not. According to Gokhale (1996), "The computer-based simulation software enables students to experiment interactively as it provides instant and reliable feedback" (p. 42). Reliable and appropriate feedback is the key, as simply putting students in front of a computer-based simulation is not sufficient to promote learning. The simulation must be situated in the context of a well-designed learning environment that supports appropriate discovery learning in the domain under study (Tan & Biswas, 2007)

Students pursuing careers in the field of science and technology are also expected to be somewhat creative and inventive. Michael (2001) conducted research to study the effect of a computer simulation activity versus hands-on activity on product creativity in technology education. It was found that there was no difference between the computer simulation group and the hands-on group when it comes to product creativity, originality, and usefulness. A study by Whiteley and Faria (1989) revealed that the performance levels on the applied and theoretical questions on the final exam were the same for students who used the simulation software versus those who did not. But these studies are not conclusive, according to Veenman, Elshout, and Busato (1994). In a guided-discovery environment, problem-oriented simulations do help develop higher-order thinking strategies and improve student cognitive abilities employed in the service of recall, problem-solving, and creativity.

Even though the study done by Kumar and Sherwood (2007) concluded that the use of simulations in scientific curriculum does help enhance problem-solving skills, are computer-simulated experiments as effective as hands-on laboratories in term of learning specific science concepts? In order to find answer to this question, we need to look at the study by Choi and Gennaro (1997). The results of their study revealed that there were no significant differences between the performance of students in the group using simulation and that of students in the group using traditional hands-on labs when it comes to learning scientific concepts. But according to a study conducted by Rieber et al. (2004),

> The way feedback is represented also matters when learning from simulations of scientific concepts and principles. Participants increased their implicit knowledge of physics when they interacted with a physics simulation given graphical feedback, but they were unable to demonstrate increased explicit understanding based on the way feedback was represented such as not providing sufficient time or guidance for interpreting the continual stream of feedback. (p. 309)

Even though simulations with feedback do help learners' increase their implicit knowledge of physics, it is not clear how such approaches will yield results in other areas of science and technology such as IT. Acording to Moreno (2004), "The importance of feedback in promoting learning is inarguable but additional research is needed to determine the effects of structured guidance on other educational areas, methods, and student populations" (p. 111). Therefore, when it comes to learning in a guided discovery-based simulated environment, further research is needed to better understand the effects of different feedback types.

Simulation and Technical Education

Historically, simulation has been most identified with aviation, but recently it has become well known in other fields such as games, technolog,y and healthcare. Today, simulations are available to support instructions in many areas of schooling including science and technology. Generally speaking, it is less expensive to develop a simulation than to provide real experience, and this is particularly true with complex devices such as flight simulators (Srinivasan et al., 2006). Incorporating and implementing state-of-the-art technological tools and equipment demands a considerable investment of time and financial resources. In the case of many training institutions where funds are usually very limited, keeping curricula and lab resources current with respect to the fast rate of change of technological advances poses a real challenge. Therefore engineering and engineering technology communities all over the world can address some of the challenges by using simulation and virtual experiments (Agrawal, & Cherner, 2009). In addition to the cost saving, simulations for technical training offer a number of other advantages, which includes the following:

- Allowing users to modify system parameters and observe the outcomes without the possibility of harming "real" expensive equipment.
- Learning trouble-shooting by fixing or replacing faulty equipment without any additional cost.
- Encouraging users to take "bold" steps in the process of discovering and understanding any technical details.
- Upholding users' interest through multimedia especially if presenting 'dry concepts'.

In recent years, a number of published studies have suggested that the incorporation of simulation in technical curricula plays a significant role in improving student learning. Garcia and Backer (2007) reported that students who used both computer simulations and hardwired experiments learned the material better. Banky and Wong (2007) observed that the use of simulation software promotes deep learning in the study of electronic circuits. Rosli and Aris (2010) concluded that simulation possesses several advantages that are highly suitable for learning physical science. Garcia and Backer (2007) reported that in simulation circuit designs can be done very quickly, and the results can be observed immediately. Deshpande and Huang (2011) concluded that proper application of simulation games in engineering education would maximize the student's transferability of academic knowledge to the industry. As a matter of fact, when it comes to learning science and technology, simulation in many cases provides the same or better experiences as the real systems, argue Srinivasan et al. (2006). A study by Rieber et al. (2004) concluded that participants' performance on the test of principle of Newtonian motion was even greater when the feedback in the simulation was presented either in the form of graphics or brief explanations. Table 1 lists some of the well-known simulation products used in the technology curriculum.

Table 1

Widely Used Software in Engineering and Technology Curricula

Software	Primary Application Areas
PSPICE	Electric and Electronic Circuits (Analog and Digital)
MultiSim	Electric and Electronic Circuits (Analog and Digital) Communications
VisSim	Electric and Electronic Circuits (Analog and Digital) Communications
Logic Works	Digital/Microprocessor Design
MATLAB	Mathematics, Control Systems, Power Systems
Packet Tracer	Cisco Routers and Switches – Computer Network Design and Trouble-shooting

Simulation and Medical Education

Medical education has been investigating the extended use of simulation for its training, especially in the area of preclinical training. According to Buchanan (2001), "Factors that appear to be driving the interest are a desire to provide a smoother transition for students into the clinic" (p. 228). Conceptual framework for the learning of clinical skills comes from the work of Lev Vygotsky (1896-1934), a Russian psychologist who described a zone of proximal development (ZPD); i.e., learners work individually or in small groups under the guidance of an expert tutor, where the level of support is adjusted according to the needs of each individual. Expert tutors such as simulation provides an environment in which guided feedback underpins the learning. Simulation offers support or guided feedback when needed but recedes into the background when not required, allowing each learner the space to process their individual learning needs. Simulation broadens the students' preclinical experience by including additional models mimicking real patient conditions and providing easy access to demonstrations, diagrams, and manuals (Buchanan, 2001).

The use of simulation in nursing curricula also has increased greatly during the past decade (Kneebone, Kidd, Nestel, & Paraskeva, 2002). Typically, nursing students are taught theory in one course and clinical skills such as fundamentals in others. They are assigned to clinical settings to apply what they have learned and to think on their feet while caring for real patients. This traditional model does not provide opportunities to practice skills and think critically in a safe environment; therefore, the move towards making simulation a part of nursing curricula, either as a clinical enhancement, substitute, or adjunct, is increasing (Jeffries, 2007).

Current outcome studies using simulation in medical education are positive and suggest much potential for shifting some traditional clinical education into the simulated learning environment (Eddy, 2007). Probably the most important reason to adopt this pedagogy is because of the ability to create standardized environments that present students with safe, problem-solving encounters that require real-time assessment and interventions for real clinical problems. According to Issenberg, McGaghie, Hart, Mayer, and Felner (2008):

> Unfortunately, most medical students and practitioners have little regular access to professional feedback with opportunities for repetition and correction of errors. The regular use of simulators incorporated into structured continuing medical education program as well as in self-assessment and self-directed remediation programs offers great promise for lifelong professional development. (p. 863)

Because of obvious benefits of simulations such as ease of repetition, instant feedback, and self-assessment, they are rapidly moving from the game and military fields into medical education. As a matter of fact, advanced technology simulation is on the verge of dramatically affecting health-care education as it has the real potential to influence and modify how we teach, such as UMedic, a multimedia simulation software with graphics and audio feedback features, has significantly improved physicians learning in the area of radiography, angiograms, and electrocardiograms treatment (Issenberg et al., 2008).

Simulation and Feedback

The use of feedback is a critically important attribute in computer-based instruction (CBI) such as multimedia simulations, as it promotes learning by providing students with information about their responses (Clariana et al., 1991). Especially when it comes to novice learners, research has demonstrated that novices do not learn as well when they are placed in unguided training environments (Institute for Creative Technologies, 2009). Novices need to be given some degree of guidance when learning new information, especially those involving complex tasks. The content of the feedback should help the novice develop accurate knowledge structures and build schema in order to better learn the information and eventually become an expert (Cuevas, Fiore, Bowers, & Salas, 2004). Therefore, feedbacks, being an essential part of a guided discovery-based learning platform such as simulation, deserve serious attention by the instructional designers.

Even though the effects of multiple types and forms of feedback have been investigated in a large variety of instructional contexts, some of the widely used feedback types in a multimedia learning environment are:

1. Knowledge-of-response (KOR), which indicates that the learner's response is correct or incorrect.
2. Knowledge-of-correct-response (KCR), which identifies the correct response.
3. Elaborative feedback, a complex form of feedback that explains, monitors, and directs, such as answer-until-correct (AUC).

A meta-analysis done by Azevedo and Bernard (1995) suggests that the achievement outcomes generally are greater for students receiving CBI that utilizes feedback than for comparison groups with no feedback. The study, however, does not provide insight into the specific type of feedback that is most effective.

Morrison, Ross, Gopalakrishnan, and Casey (1995), on the other hand, found that knowledge-of-correct response (KCR) and delayed feedback (providing feedback at the end of the testing session) within computer-based instruction (CBI) produced greater learning than answer-until-correct (AUC) or no feedback for lower level questions (declarative knowledge). For higher level questions (application or transformation knowledge), however, there were no learning differences in response to the various forms of feedback.

Clariana (1993) also examined the effects of various forms of feedback. Similar to Morrison et al. (1995), the result of his study showed that KCR was superior on identical questions. In contrast to Morrison et al. (1995), however, answer-until-correct (AUC) feedback was equivalent to knowledge-of-correct-response (KCR) and was significantly more effective than no feedback.

In the research by Clariana (1990), the researcher examined differences in the use of KCR and AUC feedback for low ability learners. The results of this study indicated that low ability students benefit more from KCR than AUC feedback, as they do not have the prerequisite knowledge to effectively reexamine and evaluate the options available during AUC feedback.

According to Moreno (2004), "The importance of feedback in promoting learning is inarguable. Previous research indicates that different types of feedback have different influences on performance" (p. 110). Several studies have shown KCR to be superior to KOR, and KOR to be superior to no feedback, but this hierarchy of immediate feedback types is not so well established (Clariana et al., 1991). AUC outperforming KCR cannot be verified, at least in the area of self-regulation, reported by Agina et al. (2011).

In addition, Kalyuga (2006) argues that presenting the proper forms of guidance and feedback are critical at different stages in the learning process, because this can directly affect how well a person can process information and whether or not effective learning will take place.

Summary

According to Corter et al. (2007), "Laboratories play a crucial role in the education of future scientists and engineers, yet there is disagreement among science and engineering educators about whether and which types of technology enabled labs should be used" (p. 17). The reason for this disagreement, in my opinion, is based on the contradicting research findings discussed above. On the one hand, simulation has proven to be an effective tool for enhancing skills such as critical thinking, problem solving, and scientific inquiry, but when it comes to fostering creativity and/or acquiring applied knowledge, the results are not very promising. Some researches argue that problem solving is indeed a creative process, such as Guliford (1976), who argues that problem-solving is creative; there is no other kind, or Hinton (1968), who believed that creativity would be better understood if placed within a problem-solving structure (as cited in Michael, 2001). Lack of any comprehensive or clear definition of variables to measure learning effectiveness, therefore, is probably another reason researchers are having difficulty conveying cohesive messages.

The use of feedback is another area which is critically important and an often-neglected attribute in simulation or multimedia-based instructions (Clariana et al., 1993). In instructional or training contexts, feedback can be defined as post-response information that is provided to learners to tell them of their real state of learning or performance (Narciss, 2008). Feedback during training is important for three primary reasons: (1) it can help to increase motivation by showing that there is a discrepancy between current performance and the desired level of performance, (2) it can reduce uncertainty of how someone is performing, and (3) it can help someone learn how to correct mistakes (Davis, Carson, Ammeter, & Treadway, 2005). For these reasons, feedback is a necessary component for training (Billings, 2010). According to Bruning and Mason (2001):

> Computer-provided feedback would seem to have several important advantages. First of all, once the requisite programming is in place, computers can tirelessly provide feedback in response to student work. Unlike feedback from an instructor or tutor, this feedback can remain unbiased, accurate, and nonjudgmental, irrespective of student characteristics or the nature of student response. In addition, the interactive ability of computers-based instruction has the potential for enhancing the quality and type of feedback that can be implemented, limited only by the ingenuity and energy of course designers. (p. 301)

An experiment was conducted by Sanders (2005) on the use of feedback to promote learning in a simulated environment where students were taught how to control unmanned vehicles and conduct reconnaissance, surveillance, and target acquisition based on predefined rules. Sanders found that feedback which identified student errors and offered a corrective action to be taken to achieve the end goal increased the learning of a new procedural skill.

But it is difficult to say which type of feedback is best, as results are mixed (Murphy, 2007). For example, summarizing the findings of Bangert-Drowns, Kulik, and Morgan (1991), AUC is considered to be the most effective, while no feedback is better than having just knowledge-of-response (KCR) feedback that states right or wrong or otherwise tells learners whether their response is correct or incorrect. However, following a review of 30 studies, Clariana's (1993) findings show feedback (KCR) has proven more effective than no feedback; but according to Jaehnig and Miller (2007), "KCR would be of little benefit to a learner who is essentially guessing" (p. 228). Therefore, uncertainty still exists as to how to select, and optimize uses of different forms of feedback depending on characteristics of students and the learning situation (Murphy, 2007).

While there are many advocates of simulations, there are also many opponents who see simulations as potentially harmful to students by depriving them of important learning experiences. It is widely accepted that a student cognitive style can affect their preferences for educational media, presumably including preferences for hands-on versus simulated labs (Corter et al., 2007). Hence, it is necessary to keep studying the effect of simulated lab and its features, such as feedback on students' learning in all the critical areas including declarative-knowledge, before any conclusive statement about its effectiveness can be made.

One way to better understand the effect of simulation on students' learning is to expand the research to unconventional areas such as information technology (IT). Even thoug, for several decades researchers have explored the use of simulation to augment the laboratory experiences in the areas of surgery, physics, chemistry, biology, math, and dental education, there is no significant study that measures the effect of students' learning of IT concepts using multimedia software that provides different forms of feedback. Therefore, conducting such research will be a big step forward in the field of instructional technology as first, it will validate the use of simulation as an instructional strategy for teaching basic IT concepts without the support of any hands-on experiments, and second, it will verify if simulation scaffolding features such as feedback can enhance students' declarative knowledge in a guided discovery-based simulated learning environment.

CHAPTER 3

METHDOLOGY

This study was designed to evaluate the effects the computer simulation feedback types have on students' learning of information technology (IT) concepts. The research approach utilized in this study was a quasi-experimental, repeated measures design. Specifically, this study compared and contrasted the performance outcomes resulting from computer simulation and traditional hands-on learning activities. Creswell (2006) provides support for the use of repeated-measures design, as it controls several of the threats to internal validity.

This chapter describes of the research design and identifies the variables. It also contains a discussion of the sampling process and the experimental treatments, followed by a description of the instructional and assessment materials utilized in the study. The chapter concludes with a description of the timeline of the study as well as the identification of the data analysis strategies employed to test the hypothesis.

The sample for the study included 80 students enrolled in the four sections of Cisco Routing Fundamentals (NETW205) course during the winter semester of 2012, offered at DeVry University, 1201 S. Swift Road, Addison, Illinois 60101. DeVry University is a Cisco Network Academy (CNA) where Cisco Certified Network Associate (CCNA) training is regularly offered throughout the year. NETW205 is one of the required courses to complete training for CCNA certification.

The Participants (Sampling)

Sampling refers to the process of selecting individuals who will be participating in a research. There are two types of sampling: random and nonrandom. The focus of this study was based on nonrandom sampling. Nonrandom sampling can be further categorized into systematic sampling, convenience sampling, and purposive sampling. The method chosen for the research was the convenience sampling, which is a group of individuals who are conveniently available for a study.

The sample for the study included 80 students enrolled in the four sections of Cisco Routing Fundamentals (NETW205) course. NETW205 is one of the required courses to complete CCNA training. There are total of four courses: Network Fundamentals (NETW203), Routing Fundamentals (NETW205), Switches and Wireless (NETW207), and Wide Area Network Technologies (NETW209). NETW203 is a prerequisite for NETW205 enrollment. One section of the NETW205 classes was assigned to the control group while the other three sections were assigned to one of the experimental groups.

All 80 participants involved in the study were enrolled to complete their CCNA certification. Classes were randomly selected and assigned to one of the four groups: . simulation- ab with AUC (AUC), simulation lab with KCR (KCR), simulation lab with no feedback (NFB), and traditional hands-on lab (HON) group. Even though all four groups were given the same lab work to complete, the AUC group was required to complete the lab using the simulation software with AUC feedback, the KCR group was required to complete the lab using simulation with KCR feedback, and the NFB group was required to complete the lab using simulation with no feedback. The hands-on HON group was asked to complete the same experiment using physical equipment in the traditional hands-on lab environment. Irrespective of the class size and the level of students' prior technical knowledge, section assignments were done as shown in Table 2. Assigning a class arbitrarily to one of these groups avoided any biasing as far as student selection and lab assignments were concerned.

Table 2

Control and Treatment Groups (20 Students Each)

Class	Group Assignment
Morning Session	Traditional Hands-on Group (HON)
Afternoon Session	Simulation with KCR Group (KCR)
Evening Session	Simulation with AUC Group (AUC)
Weekend Session	Simulation with no-feedback Group (NFB)

Through these labs students were introduced to the concept of identifying Local Area Network (LAN) devices, understanding their connectivity requirements, and selecting the right cables. These labs were primarily for the learners to understand one of the basic steps necessary to configure and troubleshoot networking devices, as without any proper interconnectivity, data routing among the devices is impossible. In order to fabricate the necessary background, all learners were required to attend the lecture session before performing any of these experiments. The lecture focused on the concept, purpose, configuration steps, and troubleshooting techniques necessary to interconnect a given computer network infrastructure.

The control group performed the experiment in a traditional hands-on lab environment while the other three treatment groups were asked to perform the same lab under three different feedback (AUC, KCR, no feedback) conditions in a simulated lab environment as outlined later in the chapter. Due to the convenience sampling approach taken here, confounding variables such as computer networking skills, attitudes towards simulation, etc. were addressed through a short survey conducted before the actual experiment (see Appendix B).

For the purpose of measuring students' cognitive (declarative-knowledge) learning outcomes the framework offered by Kraiger, Ford, and Salas (1993) was employed, as it is based on theories from a number of schools of thoughts beyond psychology. This theoretical based-model of learning outcomes is a multidimensional, construct-oriented approach to learning, cognitive, skill-based, and affective outcomes. This framework serves as a guide for aligning evaluation methods to each of specific learning outcomes. Multiple-choice speed tests (pre and post) were used to evaluate participants' declarative knowledge, as according to Kraiger et al. (1993), "The acquisition of declarative knowledge can be assessed through multiple-choice, true-false, or free-recall speed exams" (p. 314). Speed tests assess the number of items answered correctly in a given amount of time.

The Treatment

Simulation Software

In order to validate the use of simulation as an instructional strategy for basic IT concepts without the support of any hands-on experiments, and to verify if simulation's discovery learning environment supported by scaffolding features such as AUC and KCR feedbacks can enhance students' learning (declarative knowledge) in the area of information technology, simulation software produced by Cisco Systems was used. The software is known as Packet-Tracer, and the version chosen for this quantitative study was 5.3.2.

Packet-Tracer provides a guided discovery learning environment and has all the capabilities necessary to complete Cisco Certified Network Associate (CCNA) required lab experiments. From a basic router configuration to a complex LAN\WAN network design, and from a simple route troubleshooting to develop an intricate VLANs architecture, all the scenarios can be easily simulated in the Packet-Tracer. Packet-Tracer-based experiments completed on any portable device such as a laptop will exactly replicate the hands-on exercises performed in the physical lab environment. Packet-Tracer is currently being used in many onsite and online CCNA certification courses offered at many Cisco academies around the world. Figure 1 shows a screen shot of an enterprise network infrastructure being designed and evaluated in the Packet-Tracer simulated learning environment.

Packet-Tracer is a powerful computer network simulation program that allows learners to discover network behavior by asking "what if" questions. As an integral part of the Cisco Networking Academy comprehensive learning experience, Packet-Tracer provides simulation, visualization, authoring, assessment, and collaboration capabilities and facilitates the learning of complex technology concepts with the help of features such as feedback as a guiding tool.

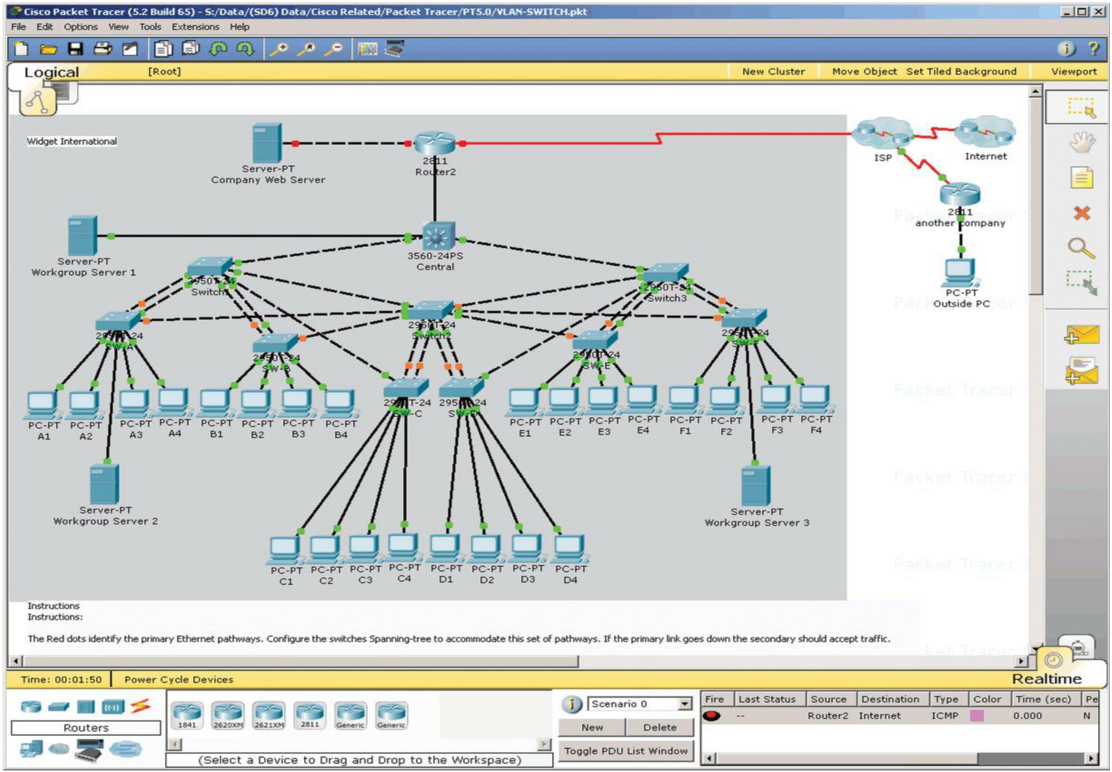

Figure: 1 Packet-Tracer Screen Shot

The current version of Packet-Tracer supports an array of simulated application layer protocols (HTTP, DNS, etc.), as well as basic routing with RIP, OSPF, and EIGRP, to the extent required by the current CCNA curriculum. (See Appendix A for a complete list of acronyms.) With the introduction of version 5.3.2, several new features were added, including BGP, which is part of the CCNA security curriculum. While Packet-Tracer aims to provide a realistic simulation of functional networks, the application itself utilizes only a small number of features found within the actual hardware running a current Cisco Operating System known as Interconnect Operating System (IOS).

Packet-Tracer Learning Environment

Packet-Tracer essentially offers three guided discovery learning environments with varying degree of technical details, known as topology, simulation, and realtime. One may switch between these modes by clicking on the topology, simulation, and realtime tabs.

In topology mode, one can build a network by choosing, connecting, and configuring devices. In terms of filtering and forwarding packets, the network is not “intelligent” at this point because network convergence hasn't occurred. One may inspect physical connectivity in this mode, but some Interconnect Operating System (IOS) diagnostic commands will not work; hence, this learning environment was not be used for the study.

In simulation mode, one may run and diagnose the network one step at a time by sending packets in the desired sequence and viewing network parameters at each hop. Certain commands, like PING and TRACEROUTE, are not suited for this step-by-step approach, as one single ping operation involves many packets being sent back and forth in the network and would take a long time. Therefore, this learning environment was also not suitable for this study.

In realtime mode, one can issue troubleshooting commands such as PING and receive a timely response. From the Cisco IOS and PC command line interfaces, the user may also issue extended PING and TRACEROUTE commands as well. All experiments by the three treatment groups were completed in this environment, as it offered experience analogous to working with the real equipment.

The Treatments (Feedbacks)

Packet-Tracer's feedback options can be customized using the Preferences tab as shown in Figure 2.

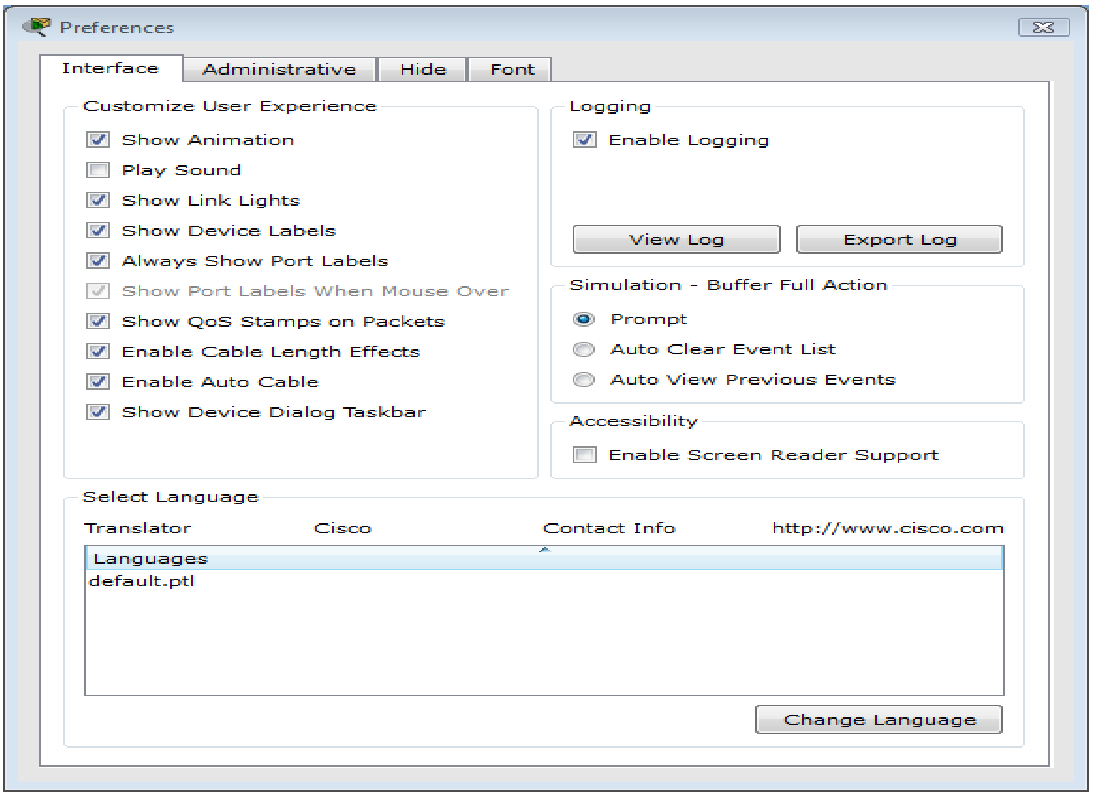

Figure: 2. Packet-Tracer Preference Tab

From the list in Figure 2, the following options were used to modify and study the effect of different feedback types (treatments) on students' learning.

- Knowledge-of-correct Response (KCR): Enabling "Show Animation" displayed the result of a selection, i.e., right or wrong, same as KCR feedback.
- Answer-until-correct (AUC): The "Enable Auto Cable" option, when unchecked,

allowed learners to keep selecting a cable from the list until the right one is chosen, same as AUC feedback.

- No Feedback: For no feedback, "Show Animation," "Show Link Lights," and "Enable Auto Cable" options were all unchecked.

The Variables

Like any experimental research, this study was also based on both dependent and independent variables. The independent variable is the one that a researcher chooses to study its possible effect(s) on one or more other dependent variables. In any study, an independent variable is supposed to affect at least one dependent variable. In this study, the independent variables are teaching methodology using traditional hands-on labs (HON) and teaching methodology using the simulation software with different feedback types, i.e., AUC-feedback (AUC), KCR-feedback (KCR), and no feedback (NFB).

The variable that the independent variable is presumed to affect is called the dependent variable. In this study, the dependent variable is the student learning. It is hypothesized that the teaching methodologies using simulation with AUC, KCR, or NFB will be at least as effective as the teaching methodology using traditional hands-on labs (HON).

The Procedure

The experiment was completed in four settings, one for each group, with each group performing the same lab (different treatment) with the same instructor (the researcher). As the researcher is also the course instructor, he/she has an advantage of attaining a disciplined lab environment and improved student participation. On the other hand, because of the teacher's respected position, some participants may view it as an enforced activity. Therefore, the researcher made certain the students were aware of their voluntarily participation.

The data collection phase of the study spanned four days, with one lab per group per day. The entire experiment sequence is shown in Table 3.

Table 3

Experiment Sequence

Event	Estimated Time (minutes)	Material
Welcome	5	Participants' Rights and Consent
Survey	2	To clarify confounded variables
Introduction	5	Experiment\Procedure Explanation
Lecture	20	Network Cabling System (PowerPoint Presentation)
Pretest	3	Pretest
Lab Work (No feedback was provided by the instructor)	20	Simulation Lab with AUC Treatment - Experiment Group -1 Simulation Lab with KCR Treatment - Experiment Group -2 Simulation with no-feedback Treatment - Experiment Group -3 Traditional Hands-on Lab – Control Group -4
Posttest	3	Posttest
Dismissal		

Welcome

Participants were greeted as they arrived at the site of the experiment. Their rights and consent were reviewed and an invitation was extended to become the part of the study. Upon oral consent, participants were asked to take any available seat in the Network Communication lab.

Survey

A short survey was conducted to gather participants' background data in terms of their computer networking skill, attitude towards simulation, familiarity with the Packet-Tracer, and seriousness towards taking CCNA exam (see appendix B).

Introduction

After all participants were seated in the lab, and the experiment procedure was explained, including the focus of the study, the lab work handout, and the possible learning outcome.

Lecture – PowerPoint

All participants were required to attend a short lecture before starting the lab. This PowerPoint based presentation was to explain the type of cables needed for any LAN\WAN infrastructure design. Except for the control group, the presentation also shed some light on the usage of the simulation software (see Appendix B).

Pretest

The experiment began with the pretest. The paper/pencil consisted of seven questions. The purpose of the test was to assess students' prior knowledge of interconnecting Cisco devices. Such exam was also to test the initial equivalence between the control and the experimental group (see Appendix B).

Lab Work – Experiment Overview

One of the key elements to design an enterprise-wide information technology infrastructure is to understand the cabling system. There are many key characteristics of cables such as length, resistance, insulation, signals, speed (bandwidth), grade, cost, protocol, topology, etc. that need to be evaluated before it can be used in a computer network infrastructure. The content/subject of the experiment was to focus on the students' understanding of the type of cables needed for a given networking devices such as hubs, switches, routers, PCs, and VoIP phones.

The type of cables offered to students to experiment with included roll-over, Ethernet straight-through, Ethernet cross-over, fiber-optic, copper phone (twisted pair), coaxial, serial DTE, and serial DCE. Students were asked to select the appropriate cable for the given networking devices that needed to be interconnected for proper operation. All three experimental groups were asked to interconnect the networking devices in the simulated lab environment as shown in Figure 3, while the control group performed the same experiment in the traditional hands-on computer lab environment.

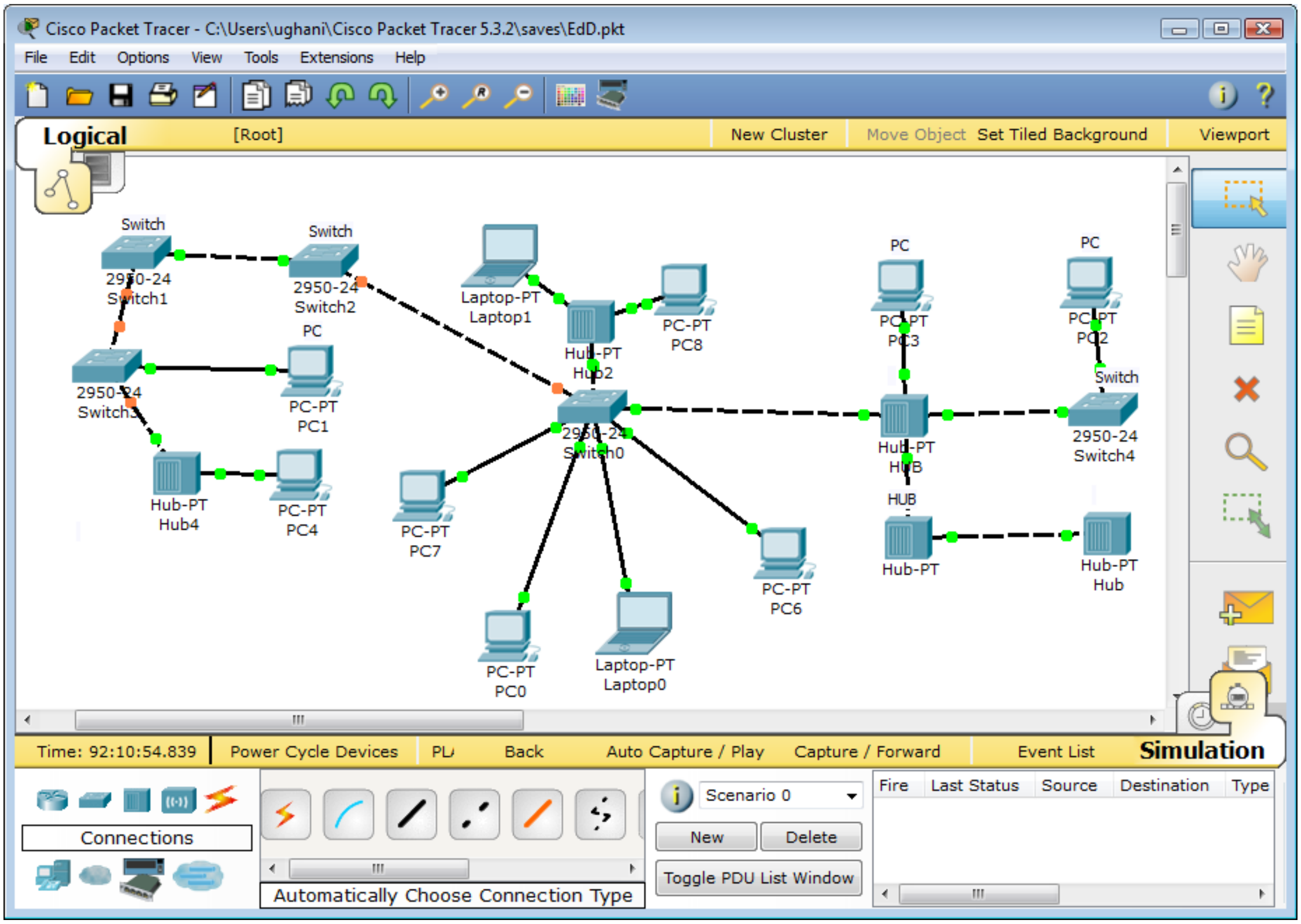

Figure 3. Simulated Lab Screen Shot.

Experiment 1 (Treatment Group 1). The purpose of this experiment was to find the answer to the research question: Does the AUC (answer-until-correct) feedback feature of simulated labs in CCNA program improve students' declarative knowledge in the learning of basic IT concepts?

In order to find the answer to this research question, treatment group 1 was provided with the Packet-Tracer configured to offer AUC feedback. Group 1 was asked to select appropriate cables necessary to interconnect networking devices as shown in Figure 3. Students were given 20 minutes to complete the lab.

The hypothesis for the experiment was: The use of simulation-based experiments with AUC feedback in the teaching of IT cabling system in CCNA program will produce either equal or greater "declarative knowledge" (as reflected in the differences between pretest and posttest scores) than the hands-on activities.

Experiment 2 (Treatment Group 2). The second research question was: Does the KCR (Knowledge-of-correct-response) feedback feature of simulated labs in CCNA program improve students' declarative knowledge in the learning of basic IT concepts?

In order to find the answer to this research question, treatment group 2 was provided with the Packet-Tracer configured to offer KCR feedback. Group 2 was asked to select appropriate cables necessary to interconnect networking devices as shown in Figure 3. Students were given 20 minutes to complete the lab.

The hypothesis for the experiment was: The use of simulation-based experiments with KCR feedback in the teaching of computer-network cabling system in CCNA program will produce either equal or greater "declarative knowledge" (as reflected in the differences between pretest and posttest trouble-shooting scores) than the hands-on activities.

Experiment 3 (Treatment Group 1). Another research question that was needed to be studied was: Does pure discovery (no feedback) based simulated labs improve students' declarative knowledge in the learning of basic IT concepts?

In order to find the answer to this research question, treatment group 3 was provided with the Packet-Tracer configured to provide no feedback. Group 3 was asked to select appropriate cables necessary to interconnect networking devices as shown in Figure 3. Students were given 20 minutes to complete the lab.

The hypothesis for the lab was: The use of simulation-based experiments with no feedback in the teaching of computer-network cabling system in CCNA program will produce either equal or greater “declarative knowledge” (as reflected in the differences between pretest and posttest challenge-section scores) than the hands-on activities.

Experiment 4 (Control Group 4). The control group was asked to perform the same lab as the other three groups but in a traditional hands-on computer lab environment as shown in Figure 4. The posttest result of the control group was then compared against the three treatment groups.

Figure 4. Hands-On Computer Lab.

Posttest

After participants completed the lab, a posttest was administered. The pretest and posttest were not identical but parallel forms of the same questions, i.e., comparable questions with the same level of difficulty. These tests were designed to measure the learning outcome (see Appendix B).

Dismissal

Each participant was allowed to leave the site once the posttest was completed. Participants were told that a copy of the results could be obtained once the data was compiled, if interested. Out of 80 participants, only 12 requested the results.

Pretest and Posttest

All labs and tests (pretest/posttest) were prepared by the DeVry University instructors who are certified by the Cisco academy. These instructors have passed Cisco Certified Associate Instructor (CCAI) certification exam necessary to teach at any Cisco Networking Academy around the world. These instructors had more than ten years of teaching experience as CCNA instructors. Both tests and labs developed for the study were very similar to the material used for CCNA training. These tests were designed to evaluate students' technical knowledge irrespective of their learning platform, whether hands-on or simulated. Both pretest and posttest were fill-in-the-blank type questions; i.e., students were asked to select answers from the pool of available responses. The focus of these tests was to evaluate students' declarative knowledge in the area of computer-network cabling system (see appendix B).

Data Analysis

Given the amount of data collected in quantitative research, computer software is usually used to analyze the data. This allows researchers to complete complex statistical analysis quickly and accurately. The data was analyzed using statistical package known as Statistical Package for the Social Sciences (SPSS) from IBM. The data analysis technique used was the analysis of variance (ANOVA), which is commonly used to determine the influence of the independent variable on the dependent variable. Using ANOVA, the average score of the two groups (control and one of the treatments) was calculated, means were compared, and standard deviation was examined for the purpose of drawing any meaningful conclusions.

In the case of ANOVA, some small violations may have little practical effect on the analysis, while other violations may render the result uselessly incorrect or uninterpretable. Therefore for cross validation, two nonparametric tests, Kruskall-Wallis and Mann-Whitney U, have been conducted as well.

In order to reduce data skewness, outliers were moved one standard deviation closer to the mean and Cronbach's alpha was used to verify its reliability. The effect size η^2 (partial eta) was calculated to validate the association between the sampled data test scores.

Hypothesis

A hypothesis is a prediction of the possible outcomes of a study. It enables the researcher to make specific predictions based on prior evidence or theoretical arguments. In this study, it was expected that the test results of the groups using the Packet-Tracer simulation software would be higher than the group that performed experiments in the traditional hands-on lab environment using physical equipment. The reason for this expectation was that the simulated environment is much convenient to work with, as less time is needed to set up the network, and more time can be spent actually performing the experiment and understanding the contents, especially if a feedback is available to identify mistakes and guide learners towards the correct answer. Therefore it was expected that the teaching methodology using simulation with AUC, KCR, or NFB would be at least as effective as the teaching methodology using traditional hands-on labs.

Validity Issues

Validity refers to the appropriateness, meaningfulness, correctness, and usefulness of the inferences a researcher makes, and validation is the process of collecting and analyzing evidence to support such inferences. Normally, there are three types of evidence a researcher can discover:

1. Content validity. Content-related evidence of validity refers to the content and format of the instrument. In this study, the format was the lab environment and the content was interconnecting Cisco devices. To maintain the validity, the lab was developed by the professional trainers, and the result was evaluated by the content experts in the field of Local Area Network (LAN) infrastructure. All professionals involved were certified by Cisco Systems as Cisco Certified Associate Instructors (CCAI).
2. Criterion validity. Criterion-related evidence of validity refers to the relationship between scores obtained using the instrument and scores obtained using one or more

other instruments or measures (often called a criterion). As Packet-Tracer was the only simulation software available on the market to learn Cisco business class devices, it was not possible to verify the criterion-related validity at this time.

3. Construct validity. Construct-related evidence of validity refers to the nature of the psychological construct or characteristic being measured by the instrument. In this study, test results were used to validate the students' learning in the area of cabling system necessary to interconnect Cisco devices.

In summary, four groups of 20 students each were involved in the study. The control group (HON) completed the experiment in the traditional hands-on lab environment while three treatment groups (NFB, KCR, AUC) completed the same experiment using the Packet-Tracer software configured with three different treatments. The pre- and posttests were conducted to measure the learning outcome. Test scores analysis and findings to the five research questions are discussed in detail in the next chapter.

CHAPTER 4

FINDINGS

This research was designed to analyze the potential impact of the use of various computer simulation feedback types on students' declarative knowledge in learning information technology concepts while preparing for the Cisco CCNA certification exam. This chapter describes the data, data analysis procedure and a summary of findings.

First, this chapter will highlight the patterns that were evident from an analysis of the collected data. Second, the quantitative findings related to the five research questions are described ,followed by a brief discussion regarding the resulting patterns. Finally, the chapter concludes with a summary of the learning outcomes regarding the use of computer simulated labs with and without any specific feedback based on the following research questions.

Research Question One: Does simulated lab with no-feedback (pure discovery) improve students' declarative knowledge in the learning of basic IT concepts as compared to hands-on experiment?

Research Question Two: Does the KCR (knowledge-of-correct-response) feedback feature of simulated labs improve students' declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments?

Research Question Three: Does the AUC (answer-until-correct) feedback feature of simulated labs improve students' declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments?

Research Question Four: Does the KCR (knowledge-of-correct-response) feedback feature of simulated labs improve students' declarative knowledge in the learning of basic IT concepts as compared to pure discovery (no feedback) simulated labs?

Research Question Five: Does the AUC (answer-until-correct) feedback feature of simulated labs improve students' declarative knowledge in the learning of basic IT concepts as compared to pure discovery (no feedback) based simulated labs?

Quantitative Findings

Participants

The sample size consisted of 80 participants, of whom 71 (88.75%) were male and 9 (11.25%) were female. They all agreed voluntarily to be a part of the research. All 80 participants were randomly but equally assigned to the following four groups of 20 members each:

1. Hands-on (HON) group
2. No-feedback (NFB) group
3. Knowledge-of-correct-response (KCR) feedback group
4. Answer-until-correct (AUC) feedback group

All participants were between the ages of 18 and 35 years, 22.75 years being the average, with AUC group demonstrating the largest standard deviation (SD = 5.59). Table 4 shows demographic characteristics in detail.

Table 4

Demographic Statistics

Group	Male	Female	Age (Mean)	Age (SD)	Total
HON	19	1	23.5	3.59	20
NFB	18	2	22.0	3.48	20
KCR	16	4	23.0	4.29	20
AUC	18	2	22.5	**5.59**	20
Total	71	9	22.75	4.27	80

Table 5 shows participants' average prior technical experience and lab preference in terms of both hands-on and Packet-Tracer (simulation). After the researcher ran the test of homogeneity, one outlier was identified and removed from the KCR computation. It is important to note the following key points:

- the AUC group had the least prior technical experience
- the NFB group was most comfortable working with the simulation software
- the HON group preferred the most working with the physical equipment though they didn't enjoy working in groups

Table 5

Survey Summary

Group	Like Working in Groups	Experience with Packet-Tracer	Like Hands-On Labs	Have Networking Experience
Hands-On (HON)	**3.50**	2.60	**2.15**	3.40
No-Feedback (NFB)	3.15	**3.05**	2.55	3.60
Knowledge-of-correct-response (KCR)	2.90	2.60	2.21	3.15
Answer-Until-Correct (AUC)	3.35	2.80	2.35	**3.80**

1-Strongly Agree, 2-Agree, 3-Neutral, 4-Disagree, 5-Strongly Disagree

Data Reliability

In order to measure the reliability of the data, Cronbach's alpha was calculated for all the four groups' pre- and posttest scores as shown in Table 6. Both tests were comprised of seven questions. As shown in Table 6, data reliability, i.e., Cronbach's alpha, is moderately low for pretest and low for posttest. In most cases, it is recommended that the alpha should be higher than 0.7, but according to Schmitt (1996), "There is no sacred level of acceptable or unacceptable level of alpha, in some cases low level alpha may still be quite useful" (p. 351). The low data reliability results here may be due to the length of the test, i.e., only 7 questions. As reported by Tavakol and Dennick (2011), "low value of alpha could be due to a low number of questions, poor interrelatedness between items or heterogeneous construct. A longer test increases the reliability of a test regardless of whether the test is homogeneous or not" (p. 55).

Table 6

Cronbach's Alpha

Test	N	Number of Items	Alpha
Pretest	80	7	.601
Postest	80	7	.270

Descriptive Analysis

Each group's data has been analyzed separately to make sure every piece of information significant to the study can be captured. The following is a description of key findings.

Hands-on group (HON): The HON group of 20 participants completed the experiment in the traditional hands-on lab environment with no feedback (help) provided either by the investigator or two lab assistants available during the experiment. Also, the experiment was conducted individually by each participant as opposed to working in groups, which is a common practice in most hands-on lab environments. The HON group pretest score ranged from 0 to 6, while the posttest score ranged from 1 to 6.The mean score for the pretest, on the other hand, is 2.30 (SD=1.592) and for the posttest is 3.85 (SD=1.136), as shown in Table 7.

Table 7

HON Group Pretest and Posttest Statistics

				Shapiro-Wilk		
Test	N	M	SD	statistic	Df	Sig
Pre	20	2.30	1.592	.912	20	.068
Post	20	3.850	1.136	.906	20	.053
Difference	20	1.550	1.986	.870	20	.012

No feedback group (NFB): The simulation with the NFB group of 20 participants, who completed the experiment in the lab using the Packet-Tracer simulation software instead of hands-on physical equipment, practiced in a traditional lab environment. All feedback features of the Packet-Tracer were disabled for the experiment. The NFB group pretest scores ranged from 0 to 6, while the posttest score ranged from 1 to 4.The mean score for the pretest, on the other hand, was 1.80 (SD=1.735) and for the posttest was 2.65 (SD=1.089), as shown in Table 8.

Table 8

NFB Group Pretest and Posttest Statistics

				Shapiro-Wilk		
Test	N	M	SD	Statistic	df	Sig
Pre	20	1.80	1.735	.877	20	.016
Post	20	2.650	1.089	.860	20	.008
Difference	20	.850	1.089	.855	20	.006

Knowledge-of-correct-response (KCR) Feedback Group: The simulation with the KCR feedback group of 20 participants completed the experiment in the lab using Packet-Tracer simulation software with all feedback features disabled except KCR. The KCR group pretest scores range from 0 to 4, while the posttest score range from 0 to 5.The mean score for the pretest, on the other hand, is 1.25 (SD=1.371) and for the posttest is 2.55 (SD=1.316), as shown in Table 9.

Table 9

KCR Group Pretest and Posttest Statistics

				Shapiro-Wilk		
Test	N	M	SD	Statistic	df	Sig
Pre	20	1.250	1.371	.831	20	.003
Post	20	2.550	1.316	.933	20	.175
Difference	20	1.30	1.341	.902	20	.044

Answer-until-correct (AUC) Feedback Group: The simulation with the AUC feedback group of 20 participants completed the experiment in the lab using Packet-Tracer simulation software instead of using hands-on physical equipment. All feedback features of the Packet-Tracer except AUC were disabled for the experiment. AUC group pretest scores range from 0 to 7, while the posttest score range from 1 to 7.The mean score for the pretest, on the other hand, is 1.80 (SD=1.794) and for the posttest is 4.25 (SD=1.712), as shown in Table 10.

Table 10

AUC Group Pretest and Posttest Statistics

				Shapiro-Wilk		
Test	N	M	SD	Statistic	df	Sig
Pre	20	1.80	1.794	.843	20	.004
Post	20	4.250	1.712	.954	20	.432
Difference	20	2.450	1.486	.934	20	.187

Assumption of Normality and Outliers

In order to test the assumption of normality, the difference between pretest and posttest scores have been analyzed for all four groups. Table 11 shows descriptive statistics and the results of the Shapiro-Wilk test for all 80 participants. It is evident that the dataset did not pass the normality test. The dataset showed a highly negative skewness of -.341.

Table 11

Shapiro-Wilk Test Results

				Shapiro-Wilk		
	n	M	SD	Statistic	Df	sig
Difference	80	1.537	1.591	.950	80	.003

As the data set didn't pass the normality test, it was imperative to spot outlier(s), if any, and truncate them appropriately. Boxplot methodology was used for this purpose; 12 outliers were detected, as shown in Figure 5.

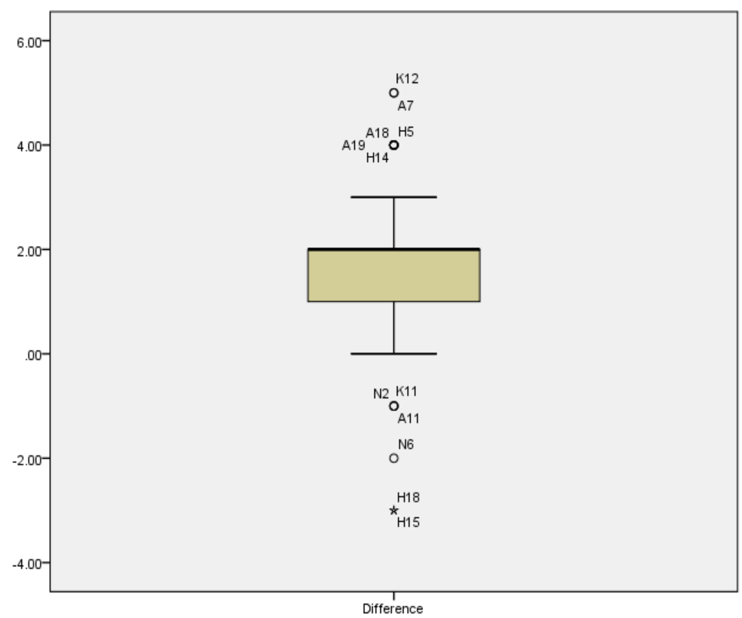

Figure 5. Outliers Boxplot.

Instead of removing the outliers from the dataset, they were moved one standard deviation (1.591) closer to the mean. Even though it helped resolve the outliers issue, it still didn't pass the normality test, though the skewness was reduced to -.038. (See Figure 6 and Table 12).

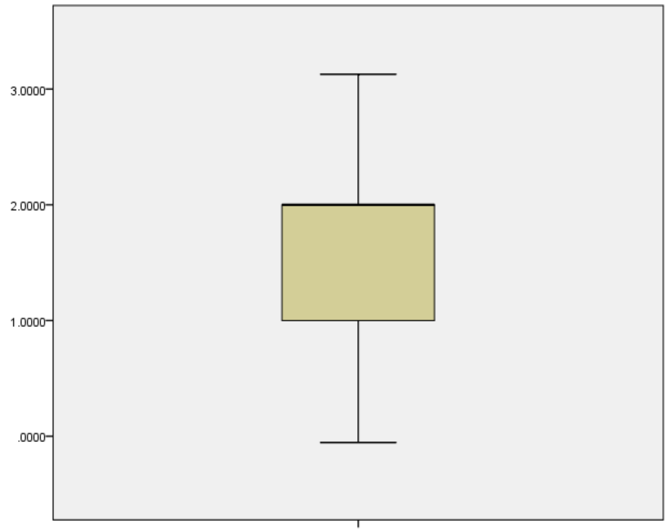

Figure 6: Boxplot after Adjusting Outliers

Table 12

Outliers

				Shapiro-Wilk		
	n	M	SD	Statistic	df	sig
Difference	80	1.548	1.115	.878	80	.000

In the case of ANOVA, some small violations may have little practical effect on the analysis, while other violations may render the result uselessly incorrect or uninterpretable. As the assumption of normality was violated here, just conducting one-way ANOVA may not produce the most reliable result. As sometimes distributions of variables do not show a normal distribution, or the samples taken are so small that one cannot tell if they are part of a normal distribution or not, the Mann-Whitney U and Kruskal Wallis tests can be used in these situations. Therefore for cross validation, both of these nonparametric tests have been conducted.

Findings to Research Questions

Research Question One

This study was designed to answer the following research question: Do pure discovery- (no feedback) based simulated labs improve students' declarative knowledge in the learning of basic IT concepts as compared to hands-on experiment? In an attempt to answer the research question, the current study tested the following null hypothesis:

> H_0: When simulated labs with no feedback (pure discovery) are practiced, the learners do not exhibit any improvement in declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments when preparing for CCNA exam.

To answer the research question and evaluate the hypothesis, a group of 20 participants completed the experiment in the traditional hands-on lab environment with no feedback (help) provided by either the investigator or two lab assistants available during the experiment. Another group of 20 participants completed the same lab in a simulated environment using Packet-Tracer with all its feedback features disabled.

Descriptive analysis. Following is the analysis of the HON (control) and NFB (treatment) groups' test scores. The differences between the pre- and posttest scores are used to evaluate the learning (declarative knowledge acquisition) of the two groups. As discussed above, the pretest score mean for the HON group is 2.30 (SD=1.592) and for the NFB group it is 1.80 (SD=1.735), the posttest score mean for the HON group is 3.85 (SD=1.136) and for the NFB group, it is 2.65 (SD=1.089).

Figure 7 shows the HON and NFB groups' mean tests score before and after completing their respective lab, demonstrating the fact that more learning took place when students were working with the physical equipment in the traditional lab environment as compared to experimenting with the simulation software with no feedback.

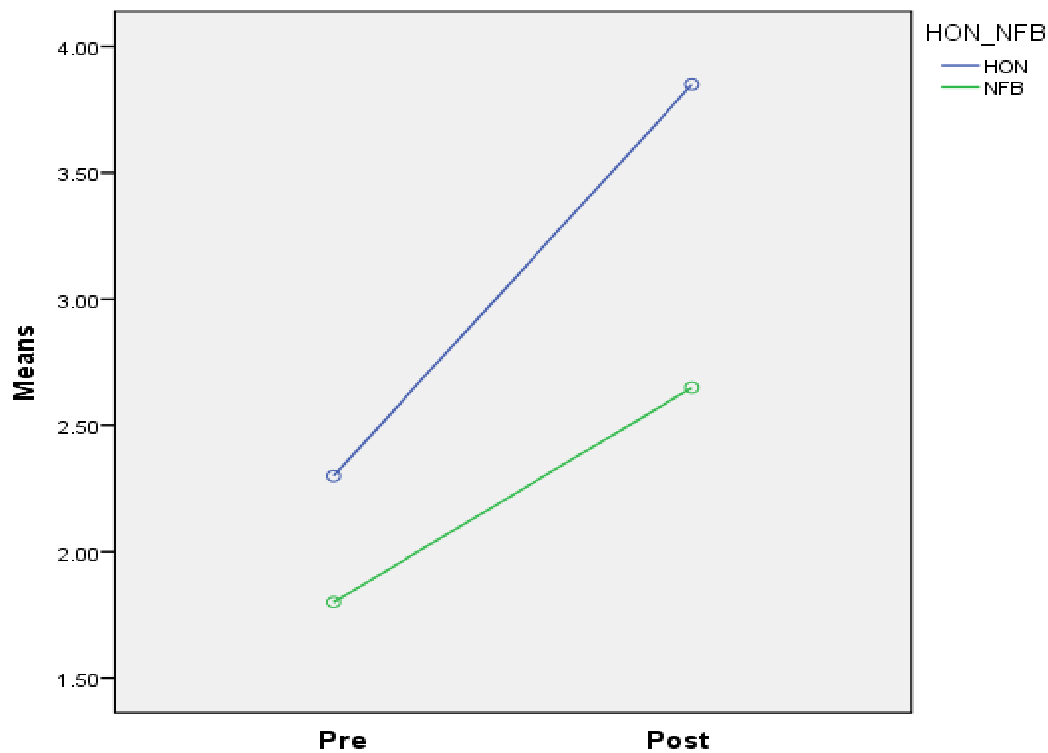

Figure 7. Mean Score – Pretest and Posttest for HON and NFB Groups.

General linear model repeated measures analysis. Repeated measures analysis of variance (ANOVA) was conducted to assess the potential difference in HON and NFB mean scores. Both assumptions of homogeneity and sphericity were not met. The Greenhouse-Geisser correction was applied in the analysis of the data. A probability level of .05 was used as the criterion for statistical significance.

The plot of means is illustrated in Table 13. Results do not indicate the existence of significant improvement in scores: $F(1, 38) = 1.910$, $p = .175 > 05$.The computed effect size of η^2 (partial eta) = 0.048 also suggests a reasonable association between HON and NFB test scores.

Table 13

Interaction Effects on HON and NFB groups

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Lab	Greenhouse-Geisser	28.80	1	28.80	22.449	.000
Lab*Group	Greenhouse-Geisser	2.450	1	2.450	1.910	.175
Error(Lab)	Greenhouse-Geisser	48.750	38	1.283		

Therefore, based on the ANOVA test results, statistically there is no significant difference that exists between HON and NFB test scores. In other words, the null hypotheses will not be rejected: When simulated labs with no feedback (pure discovery) are practiced, the learners do not exhibit any improvement in declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments when preparing for the CCNA exam.

Research Question Two

This study was designed to answer the following research question: Does a simulated lab with KCR feedback improve students' declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments? In an attempt to answer the research question, the current study tested the following null hypothesis:

> H_0: When simulated labs with KCR feedback are practiced, the learners do not exhibit any improvement in declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments when preparing for CCNA exam.

To answer the research question and evaluate the hypothesis, a group of 20 participants completed the experiment in the traditional hands-on lab environment with no feedback (help) provided either by the investigator or two lab assistants available during the experiment. Another group of 20 participants completed the same lab in simulated environment using Packet-Tracer with KCR feedback enabled.

As discussed above, the pretest score mean for the HON group is 2.30 (SD=1.592) and for the KCR group it is 1.250 (SD=1.371), the posttest score mean for the HON group is 3.85 (SD=1.136) and for the KCR group it is 2.55 (SD=1.316).

Figure 8 shows the HON and KCR groups' mean tests score before and after completing their respective lab, demonstrating the fact that more learning took place when students were working with the physical equipment in the traditional lab environment as compared to experimenting with the simulation software with KCR feedback.

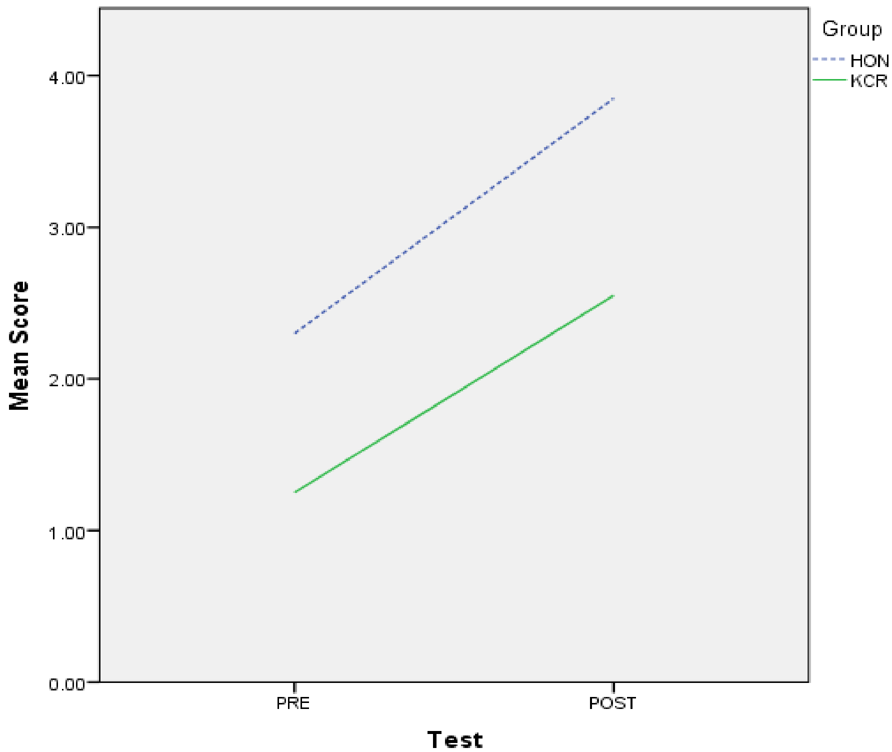

Figure 8. Mean Score – Pretest and Posttest for HON and KCR Groups.

General linear model repeated measures analysis. Repeated measures analysis of variance (ANOVA) was conducted to assess the potential difference in HON and KCR mean scores. Neither assumptions of homogeneity and sphericity were met. The Greenhouse-Geisser correction was applied in the analysis of the data. A probability level of .05 was used as the criterion for statistical significance.

The plot of means is illustrated in Table 14. Results do not indicate the existence of significant improvement in scores, i.e. $F(1, 38) = .218$, $p = .644 > .05$. The computed effect size of η^2 (partial eta) = 0.006 also suggests a small association between HON and KCR test scores.

Table 14

Interaction Effects on HON and KCR Groups

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Lab	Greenhouse-Geisser	40.613	1	40.163	28.278	.000
Lab*Group	Greenhouse-Geisser	.313	1	.313	.218	.644
Error(Lab)	Greenhouse-Geisser	54.575	38	1.436		

Based on the ANOVA test results, statistically there is no significant difference that exists between HON and KCR test scores. The null hypotheses will not be rejected: When simulated labs with KCR feedback are practiced, the learners do not exhibit any improvement in declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments when preparing for the CCNA exam.

Research Question Three

This study was designed to answer the following research question: Does simulated lab with AUC feedback improve students' declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments? In an attempt to answer the research question, the current study tested the following null hypothesis:

H_0: When simulated labs with AUC feedback are practiced, the learners do not exhibit any improvement in declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments when preparing for the CCNA exam.

To answer the research question and evaluate the hypothesis, a group of 20 participants completed the experiment in the traditional hands-on lab environment with no feedback (help) provided either by the investigator or two lab assistants available during the experiment. Another group of 20 participants completed the same lab in a simulated environment using Packet-Tracer with AUC feedback enabled.

As discussed previously, the pretest score mean for the HON group is 2.30 (SD=1.592) and for the AUC group it is 1.80 (SD=1.794); the posttest score mean, on the other hand, for the HON group is 3.85 (SD=1.136) and for the AUC group it is 4.250 (SD=1.712).

Figure 9 shows the HON and AUC groups' mean tests score before and after completing their respective lab, demonstrating the fact that less learning took place when students were working with the physical equipment in the traditional lab environment compared to experimenting with the simulation software with AUC feedback.

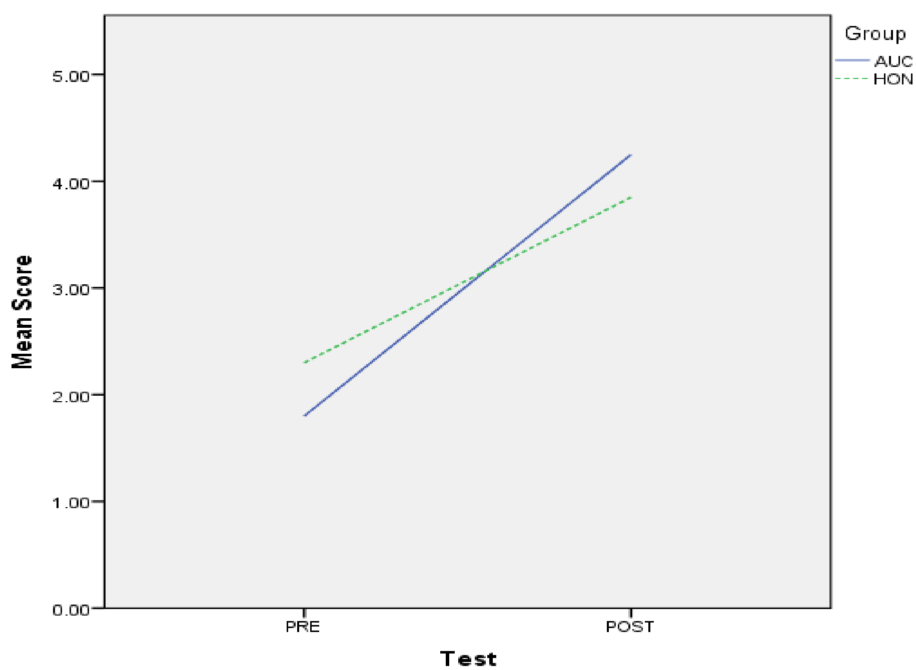

Figure 9. Mean Score – Pretest and Posttest for HON and AUC Groups.

General linear model repeated measures analysis. Repeated measures analysis of variance (ANOVA) was conducted to evaluate the potential difference in HON and AUC mean scores. Neither assumptions of homogeneity and sphericity were met. The Greenhouse-Geisser correction was applied in the analysis of the data. A probability level of .05 was used as the criterion for statistical significance.

The plot of means is displayed in Table 15. Results do not indicate the existence of significant improvement in scores i.e. $F(1, 38) = 2.656$, $p = .111 > .05$. The computed effect size of η^2 (partial eta) = 0.065 also suggests a reasonable association between HON and AUC test scores.

Table 15

Interaction Effects on HON and AUC Groups.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Lab	Greenhouse-Geisser	80.00	1	80.00	52.459	.000
Lab*Group	Greenhouse-Geisser	4.050	1	4.050	2.656	.111
Error(Lab)	Greenhouse-Geisser	57.950	38	1.525		

Therefore, based on the ANOVA test results, statistically there is no significant difference that exists between HON and AUC test scores. The null hypotheses will not be rejected: When simulated labs with AUC feedback are practiced, the learners do not exhibit any improvement in declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments when preparing for the CCNA exam.

Research Question Four

This study was designed to answer the following research question: Does a simulated lab with KCR feedback improve students' declarative knowledge in the learning of basic IT concepts as compared to simulation with no-feedback (NFB)?

In an attempt to answer the research question, the current study tested the following null hypothesis:

> H_0: When simulated labs with KCR feedback are practiced, the learners do not exhibit any improvement in declarative knowledge in the learning of basic IT concepts as compared to simulated labs with no-feedback (NFB) experiments when preparing for the CCNA exam.

As discussed previously, the pretest score mean for the NFB group is 1.80 (SD=1.735) and for KCR group it is 1.250 (SD=1.371); the posttest score mean, on the other hand, for the NFB group is 2.650 (SD=1.089) and for the KCR group it is 2.550 (SD=1.316).

Figure 10 shows NFB and KCR groups' mean tests score before and after completing their respective lab, demonstrating that more learning took place when students were working with the KCR-enabled simulation as compared to experimenting with the simulation software with no feedback.

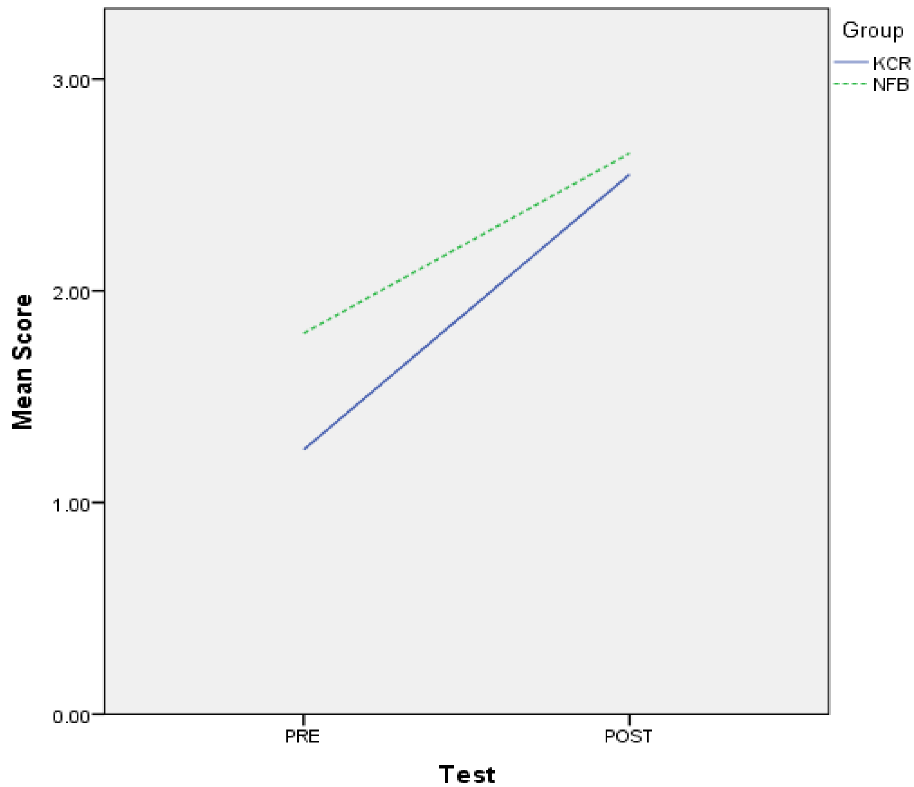

Figure 10. Mean Score – Pretest and Posttest for NFB and KCR Groups.

General linear model repeated measures analysis. Repeated measures analysis of variance (ANOVA) was conducted to assess the potential difference in NFB and KCR mean scores. Neither assumptions of homogeneity and sphericity were met. The Greenhouse-Geisser correction was applied in the analysis of the data. A probability level of .05 was used as the criterion for statistical significance.

The plot of means is displayed in Table 16. Results do not indicate the existence of significant improvement in scores i.e. $F(1, 38) = 1.356$, $p = .251 > .05$. The computed effect size of η^2 (partial eta) = 0.034 also suggests a reasonable association between NFB and KCR test scores.

Table 16

Interaction effects on NFB and KCR Groups

Source		Type III Sum of Squares	Df	Mean Square	F	Sig.
Lab	Greenhouse-Geisser	23.113	1	23.113	30.952	.000
Lab*Group	Greenhouse-Geisser	1.013	1	1.013	1.356	.251
Error(Lab)	Greenhouse-Geisser	28.375	38	.747		

Therefore, based on the ANOVA test result, statistically there is no significant difference that exists between NFB and KCR test scores. The null hypotheses will not be rejected: When simulated labs with no feedback are practiced, the learners do not exhibit any improvement in declarative knowledge in the learning of basic IT concepts as compared to simulation with KCR feedback when preparing for the CCNA exam.

Research Question Five

This study was designed to answer the following research question: Does simulated lab with AUC feedback improve students' declarative knowledge in the learning of basic IT concepts as compared to simulation with no feedback (NFB)?

In an attempt to answer the research question, the current study tested the following null hypothesis:

H_0: When simulated labs with AUC feedback are practiced, the learners do not exhibit any improvement in declarative knowledge in the learning of basic IT concepts as compared to simulated labs with no-feedback (NFB) experiments when preparing for CCNA exam.

As discussed previously, the pretest score mean for the NFB group is 1.80 (SD=1.735) and for the AUC group it is 1.80 (SD=1794); the posttest score mean, on the other hand, for the NFB group is 2.650 (SD=1.089) and for the AUC group it is 4.250 (SD=1.712).

Figure 11 shows NFB and AUC groups' mean tests score before and after completing their respective lab, demonstrating that more learning took place when students were working with the AUC-enabled simulation as compared to experimenting with the simulation software with no feedback.

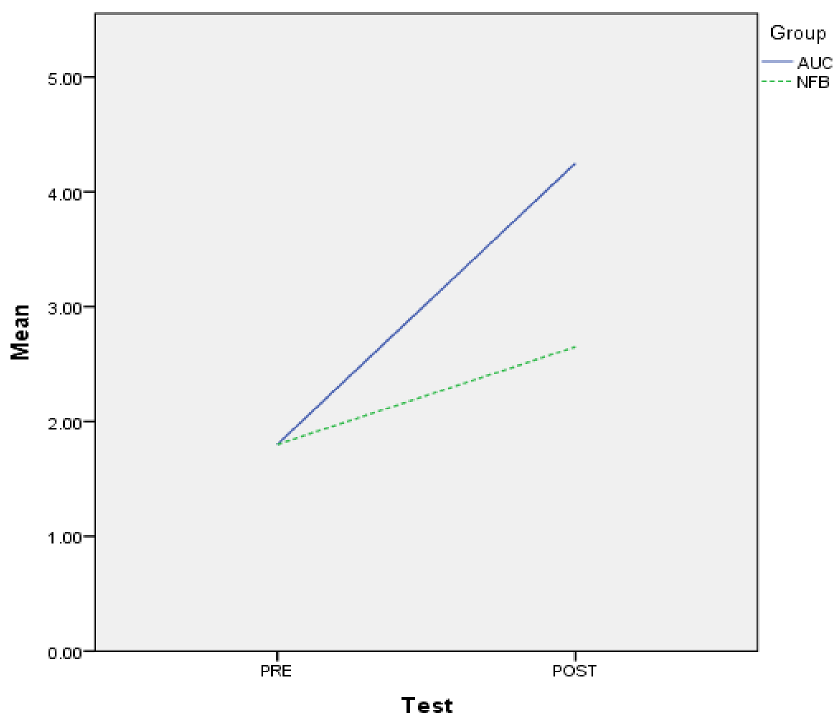

Figure 11. Mean Score – Pretest and Posttest for NFB and AUC Groups.

General linear model repeated measures analysis. Repeated measures analysis of variance (ANOVA) was conducted to evaluate the potential difference in NFB and AUC mean scores. Neither assumptions of homogeneity and sphericity was met. The Greenhouse-Geisser correction was applied in the analysis of the data. A probability level of .05 was used as the criterion for statistical significance.

The plot of means is illustrated in Table 17. The results do not indicate the existence of significant improvement in scores i.e. $F(1, 38) = 15.320$ $p = .000 < .05$. The computed effect size of η^2 (partial eta) = 0.287 also suggests a strong association between NFB and AUC test scores.

Table 17

Interaction Effects on NFB and AUC Groups.

Source		Type III Sum of Squares	Df	Mean Square	F	Sig.
Lab	Greenhouse-Geisser	54.450	1	54.450	65.169	.000
Lab*Group	Greenhouse-Geisser	12.80	1	12.80	15.320	.000
Error(Lab)	Greenhouse-Geisser	31.750	38	.836		

Thus, based on the ANOVA test result, statistically there exists a significant difference between NFB and AUC test scores. Te null hypotheses will be rejected: When simulated labs with AUC-feedback are practiced, the learners do exhibit improvement in declarative knowledge in the learning of basic IT concepts as compared to simulation with no feedback when preparing for CCNA exam.

Cross-Validation (Nonparametric Analysis)

As the populations from which data to be analyzed by a one-way analysis of variance (ANOVA) were sampled violate the assumption of normality, it was imperative to conduct nonparametric analysis as well for any trustworthy comparison and/or conclusion. The Kruskal-Wallis test is the nonparametric test equivalent to the one-way ANOVA to allow the comparison of more than two independent groups. Table 18 shows the output when the test was conducted on the dataset comprised of four groups.

Table 18

Cross Validation Kruskal-Wallis Test Result

Group	N	Rank
HON	20	43.75
NFB	20	29.30
KCR	20	35.30
AUC	20	53.65

	HON-NFB
Chi-Square	13.034
df	3
Asymp. Sig.	.005

There exists a statistically significant difference between the groups' mean scores (H(4) = 13.034, $p = .005 < .05$), with a mean rank of 43.75 for HON, 29.30 for NFB, 35.30 for

KCR and 53.65 for AUC group. As we know, Kruskal-Wallis test is an omnibus test statistic and cannot tell us which specific groups were significantly different from each other; it only tells us that at least two groups were different. In order to further analyze the data, Mann-Whitney tests between the groups were conducted. As the Kruskal-Wallis test indicated that there is a significant score difference between at-least one of the four groups, the Mann-Whitney U test was used to identify those specific groups.

Between HON and NFB Groups

Results of the Mann-Whitney U test is shown in Table 19. Statistically there is no significant difference: ($U = 130$, $p = .053 > .0125$).

Table 19

Mann-Whitney U Test Result for HON and NFB Groups

Group	N	Mean Rank	Sum of Ranks
HON	20	24.00	480.00
NFB	20	17.99	340.00
Total	40		

	Difference
Mann-Whitney U	130.00
Wilcox W	340.00
Z	-1.937
Asymp. Sig.	.053
Exact Sig.	.060

Between HON and KCR Groups

The result of fthe Mann-Whitney U test is shown in Table 20; statistically there is no significant difference: (U = 157, p =.235>.0125).

Table 20

Mann-Whitney U Test for HON and KCR Groups.

Group	N	Mean Rank	Sum of Ranks
HON	20	22.65	453.00
KCR	20	18.35	367.00
Total	40		

	Difference
Mann-Whitney U	157.00
Wilcox W	367.00
Z	-1.188
Asymp. Sig.	.235
Exact Sig.	.253

Between HON and AUC Groups

The result of the Mann-Whitney U test is shown in Table 21; statistically there is no significant difference: (U = 152, p =.186>.0125).

Table 21

Mann-Whitney U Test Result for HON and AUC Groups

Group	N	Mean Rank	Sum of Ranks
HON	20	18.10	362.00
AUC	20	22.90	458.00
Total	40		

	Difference
Mann-Whitney U	152.00
Wilcox W	362.00
Z	-1.324
Asymp. Sig.	.186
Exact Sig.	.201

Between NFB and KCR Groups

The result of the Mann-Whitney U test is shown in Table 22. Statistically there is no significant difference: (U = 169.5, p =.390>.0125).

Table 22

Mann-Whitney U Test Result for NFB and KCR Groups

Group	N	Mean Rank	Sum of Ranks
NFB	20	18.98	379.00
KCR	20	22.03	440.00
Total	40		

	Difference
Mann-Whitney U	169.50
Wilcox W	379.50
Z	-.860
Asymp. Sig.	.390
Exact Sig.	.414

Between NFB and AUC Groups

The result of the Mann-Whitney U test is shown in Table 23. Statistically there is significant difference: ($U = 76.5$ $p = .001 < .0125$).

Table 23

Mann-Whitney U Test Result for NFB and AUC Groups

Group	N	Mean Rank	Sum of Ranks
NFB	20	14.33	286.50
AUC	20	26.68	533.50
Total	40		

	Difference
Mann-Whitney U	76.50
Wilcox W	286.50
Z	-3.440
Asymp. Sig.	.001
Exact Sig.	.001

Summary

The following is a summary of findings after running repeated measures analysis of variance (ANOVA) followed by Kruskal-Wallis and Mann-Whitney U tests for cross validation:

- Simulated labs with no feedback statistically do not produce better results than the hands-on physical activities when it comes to improving declarative knowledge in the learning of basic IT concepts.

- Simulated labs with KCR feedback statistically do not produce better results than the hands-on physical activities when it comes to improving declarative knowledge in the learning of basic IT concepts.
- Simulated labs with AUC feedback statistically do not produce better results than the hands-on physical activities when it comes to improving declarative knowledge in the learning of basic IT concepts.
- Simulated labs with KCR feedback statistically do not produce better results than the simulated labs with no feedback when it comes to improving declarative knowledge in the learning of basic IT concepts.
- Simulated labs with AUC feedback statistically do produce better results than the simulated labs with no feedback when it comes to improving declarative knowledge in the learning of basic IT concepts.

CHAPTER 5

DISCUSSION AND CONCLUSION

Even though the effects of multiple types and forms of simulation feedbacks have been investigated in a large variety of instructional contexts, uncertainty still exists as to how to select and optimize uses of different forms of feedback depending on characteristics of students and the learning situation (Murphy, 2007). In order to better understand the effects of simulated labs with or without any feedback on students' learning of information technology concepts on a guided discovery-based multimedia platform, the following feedback types were investigated:

- Knowledge-of-correct-response (KCR) simply notifies the test taker when a response is correct or incorrect and identifies the correct response if necessary.
- Answer-until-correct (AUC) is a complex form of feedback that explains, monitors, and directs learners. Students ultimately select the correct answer before moving on to another item.

As mentioned previously, this study was designed to analyze the potential impact that the use of computer simulation-based instructional strategies has upon students' learning while preparing for the Cisco Certified Network Associate certification exam. This study proceeded with five research questions in order to compare and analyze the impact of simulation feedback types have on students' learning. The summary of the findings follow.

Summary of the Findings

As discussed in the previous chapter, after running repeated measures analysis of variance (ANOVA) followed by Kruskal-Wallis and Mann-Whitney U tests for cross-validation, it was established that:

- Simulated labs with no feedback statistically are not better than the hands-on physical activities when it comes to improving declarative knowledge in the learning of basic IT concepts
- Simulated labs with KCR feedback statistically are not better than the hands-on physical activities when it comes to improving declarative knowledge in the learning of basic IT concepts
- Simulated labs with AUC feedback statistically are not better than the hands-on physical activities when it comes to improving declarative knowledge in the learning of basic IT concepts
- Simulated labs with KCR feedback statistically are not better than the simulated labs with no feedback when it comes to improving declarative knowledge in the learning of basic IT concepts
- Simulated labs with AUC feedback statistically are better than the simulated labs with no feedback when it comes to improving declarative knowledge in the learning of basic IT concepts

The following section presents a detailed discussion of the findings to each research question, followed by the recommendations and implications the results have on instructional strategies, especially in the area of information technology. Research limitations and information about possible future research are discussed.

Discussion of the Findings

Research Question One

Does pure discovery-based (no feedback) simulated lab improve students' declarative knowledge in the learning of basic IT concepts as compared to the hands-on experiment? As the findings of the study didn't reject the null hypothesis, the conclusion was made that the simulated labs with no feedback are not better than the traditional hands-on lab experiments; in other words, simulated labs are at least as effective as hands-on labs in learning IT concepts.

It is interesting to note that the results did validate the research findings reported in the literature, such as, "The use of simulations to complete traditional hands-on laboratory work didn't seem to affect the overall performance," reported by Kennepohl (2001, p. 63), and simulation in many cases provides effectively the same experiences as the real systems according to Srinivasan (2006). But the result did not verify the claim that "Simulated labs can be better than the hands-on labs", as reported by Corter et al. (2007, p. 35). Therefore, while replacing traditional hands-on lab with simulated lab is recommended for at least equal effectiveness, more research is needed to substantiate its superiority.

One possible future research methods may be to include experienced Packet-Tracer users, as among the four groups, NFB participants had the least experience with the software.

The absence of having any reasonable experience with the simulated lab environment may have had an effect on the learning outcome.

Research Question Two

Does a simulated lab with KCR feedback improve students' declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments? As the findings of the study didn't reject the null hypothesis, the conclusion was made that the simulated labs with KCR feedback are not better than the traditional hands-on lab experiments; in other words, simulated labs with KCR feedback are as effective as hands-on labs.

It is significant to note that the result was in disagreement with the past studies. For example, a study done by Rieber et al. (2004) concluded that participants' performance on the test was greater when the feedback in the simulation was presented either in the form of graphics or brief explanations. The reason for this discrepancy may be due to one or more of the following:

1. Lab preference. Based on the survey conducted during the study, it was revealed that the KCR participants preferred experimenting with the physical equipment in a traditional hands-on lab environment as opposed to working with Packet-Tracer. This may have caused some lack of interest while working with the simulated lab and, therefore, the reason for the low results in this study were that each participant was asked to complete the lab individually. Survey results showed that the KCR participants were more comfortable working in groups than working individually in

the computer lab. Such arrangements may have caused the lack of support and collaboration they were expecting and therefore they did not perform well.

2. Feedback type. The Packet-Tracer simulation software provided feedback in terms of right or wrong answers with no explanation whatsoever. Such limited guidance or scaffolding might have caused commotion rather than the support novice learners were looking for. Lack of appropriate feedback could have been another reason for KCR participants' poor performance.

The participants of the study were novices in the field of IT and also had limited experience with Packet-Tracer. In order to better understand the impact of KCR feedback on students' learning of IT concepts, future researchers should consider recruiting senior students for the study; such population will have reasonable experience with the simulated labs and, therefore, will be more comfortable working individually.

Research Question Three

Does simulated lab with AUC feedback improve students' declarative knowledge in the learning of basic IT concepts as compared to hands-on experiments? As the findings of the study didn't reject the null hypothesis, the conclusion was made that the simulated labs with AUC feedback statistically are not better than the traditional hands-on lab experiments; in other words, simulated labs with AUC feedback are as effective as hands-on labs when it comes to improving declarative knowledge in the learning of basic IT concepts.

This result was again in disagreement with the past studies. For example, according to Murphy (2007), "AUC effectiveness can be contributed to its close association with the guided discovery" (p. 109), and Guillaume (2003) found that "simulations can be more effective than hands-on when formative feedback such as AUC is practiced" (p. 424). The reason for this disagreement may be due to one or more of the following:

1. IT experience. Among all the four groups, AUC participants had the least IT (computer networking) experience. Such limited experience may have been the cause of small improvement in score compared to other groups especially the HON group.
2. Individual verses teamwork. For this study, each participant was asked to complete the lab individually. Survey results showed that the AUC participants were more comfortable working in groups than working individually in the computer lab. Such an arrangement may have caused the lack of support and collaboration they were expecting, and therefore they did not perform well.
3. Feedback type. ThePacket-Tracer simulation software provided feedback in terms of right or wrong answers with no explanation whatsoever. Such feeble guidance or scaffolding might have caused commotion rather than the support novice learners were looking for. Lack of appropriate feedback could have been another reason for AUC participants' poor performance.
4. Simulation experience. According to the survey, AUC participants' experience with the Packet-Tracer simulation software was not very strong. Lack of needed software experience may be another reason for AUC group not to score well as compared to the HON group.

The participants of the study had a limited experience both with Packet-Tracer and computer networking technology. In order to better understand the impact of AUC feedback on students' learning, future researchers should consider recruiting participants who have some networking experience and/or are very comfortable with Packet-Tracer.

Research Question Four

Does a simulated lab with KCR feedback improve students' declarative knowledge in the learning of basic IT concepts as compared to simulation with no feedback (NFB)? As the findings of the study didn't reject the null hypothesis, it was concluded that the simulated labs with KCR feedback are not better than the simulated labs with no feedback when it comes to improving declarative knowledge in the learning of basic IT concepts.

This result was in disagreement with the past studies. For example, according to Murphy (2007), "Students receiving KCR feedback scored higher when working alone" (p. 424), Clariana, Ross, & Morrison (1991) reported that "KCR is more effective than no feedback" (p.15), and no feedback is inferior to KCR (Jaehnig & Miller, 2007). The reason for this disagreement may be due to one or more of the following:

1. Lab preference. Based on the survey conducted for the study, KCR participants preferred experimenting with the physical equipment in a traditional hands-on lab environment more than the NFB group. Therefore, this may have caused some participants to lose their interest while completing the experiment with the help of Packet-Tracer.
2. Individual versus teamwork. For this study, each participant was asked to complete the lab individually. Compared to the NFB group, KCR participants were not comfortable with such an arrangement; instead they preferred working in groups. This may have

caused the lack of support and collaboration they were expecting, and therefore they did not perform well.

3. Feedback type. The Packet-Tracer simulation software provided the feedback in terms of right or wrong answers with no explanation whatsoever. Such feeble guidance or scaffolding might have caused commotion rather than the support novice learners were looking for. Lack of appropriate feedback could have been another reason for the KCR groups' poor performance.

In order to better understand the impact of KCR feedback on students' learning, future researchers should consider recruiting students who prefer working individually and enjoy performing labs in a simulated environment.

Research Question Five

Does a simulated lab with AUC feedback improve students' declarative knowledge in the learning of basic IT concepts as compared to simulation with no feedback (NFB)? As the findings of the study rejected the null hypothesis, it was concluded that the simulated labs with AUC feedback statistically have better results than the simulated labs with no feedback when it comes to improving declarative knowledge in the learning of basic IT concepts.

The result was in agreement with the past studies. For example, summarizing findings by Bangert-Drowns et al. (1991), AUC feedback is considered to be the most effective. Morrison et al. (1995) reported that "Answer-until-correct (AUC) feedback was significantly more effective than no feedback" (p. 48), and, according to Jaehnig and Miller (2007), "In comparison of AUC with a no-feedback condition, AUC was found to be superior" (p.230).

The reasons for AUC's superiority may be due to the requirement that the learners stay engaged until they respond correctly, and the last answer the learner makes is the correct one.

Implications of Simulations in Learning Environments

Hands-On or Simulated Labs

Laboratories play a key role in the education of future scientists and engineers, yet there is disagreement among science and engineering educators about whether and which types of technology-enabled labs should be used (Corter et al. 2007). This study was designed precisely to address this dispute. The first three hypotheses involved a comparison of the hands-on experiment and simulation labs with or without any feedback type such as KCR and AUC. It is interesting to note that the study showed no advantage for simulated labs under any feedback condition over hands-on experiments. The finding was similar to the observation made by Corter et al. (2007), "There was no significant difference in lab test scores when experimenting with either simulation or hands-on physical equipment" (p. 35). According to Jeffries, Woolf, and Linde (2003),

> There were no significant differences in test scores between the two groups using either hands-on or computer-based interactive multimedia program to learn clinical skills. Overall results indicated that both groups were satisfied with their instructional method and were similar in their ability to demonstrate the skill correctly. (p. 72)

But other studies have shown that in certain cases simulation is more effective than the hands-on exercises. According to LeMaster (2005), students who worked with computer simulations are more capable at constructing circuits than their counterparts who have been working with the real equipment all along" (p.). Cooke (2008) reported that when medical simulation was incorporated into residency program it improved performance of specific skills, team leadership, and communication. Leung (2011) found that based on head-to-head hands-on comparison ,simulation is more credible option for basic learning. So what are some possible reasons for these disparate findings? A few probable causes may be:

Students' perception. In spite of the evidence in the study that the learning outcomes, either by the traditional hands-on or simulated lab activities, were equal, participants' self-assessment gave a slightly different picture. Overall, most participants preferred traditional hands-on labs over simulated labs, which is similar to the findings observed by Corter et al. (2007), "Students rated traditional hands-on labs as higher in educational effectiveness than the remote and simulated labs" (p. 20). According to Ma and Nickerson, (2006), "It is obvious that the effectiveness of laboratory may be affected by how much students believe in them" (p. 141). Such perception, therefore, may have played a role subsiding learners' interest while working with the simulated lab and hence demonstrated no improvement.

Lab arrangements. In the study, the hands-on group was asked to perform the lab individually, rather than working in groups, which is a common practice in most schools and colleges around the country, including DeVry. Teamwork is practiced due to the lack of on-campus resources to run the labs with sufficient laboratory equipment (Striegel, 2001). Therefore, the participants performing the assigned activity individually in a traditional hands-on lab environment may have resulted in improved learning which may otherwise have not been possible.

Basic versus advanced topics. According to Corter e al. (2007),

> The order in which different lab formats are experienced may have an effect. Simulated labs scores increase in the second experiment if the first was hands-on

> especially for the complex topics, which are difficult to fully understand without the benefit of direct physical contact with the apparatus. (p. 36)

Learning new IT concepts, therefore, may have favored the HON group much more than the three simulated-lab groups involved in the study.

Simulation experience. The Packet-Tracer simulation software used in this study is strictly for academic use. Students entering Cisco academies for CCNA certification usually have no pre-exposure to the software, which is consistent with the survey results reported in Chapter 4. Such limited experience may have negatively affected the learning outcome, as a lack of software experience and support is a significant factor in computer nervousness (Todman & Drysdale, 2004).

Consistent with the literature such as reported by Corter et al. (2007), "Simulated labs can be at least as effective as traditional hands-on labs in teaching specific course concepts" (p. 36), the findings did verify the studies; however, the question whether the simulated labs with or without any feedback is superior to hands-on labs needs further investigation.

Before making any solid recommendation in the favor of simulated labs, further research is needed due to the following concerns: first, most science and engineering educators believe that the hands-on experience of the science laboratory is a necessary supplement (Schwartz & Dunkin, 2000); second, student cognitive style can affect their preferences for educational media (Corter et al., 2007); third, it is clear that students learn not only from equipment, but from interactions with peers and teachers (Ma & Nickerson, 2006); and fourth, excessive exposure to simulation will result in a disconnection between real and virtual worlds (Magin & Kanapathipillai, 2000). Until we have concrete answers to these questions, recommendations to replace traditional hands-on with simulated labs in the learning of IT concepts cannot be crystallized.

Feedback or No Feedback

The last two hypotheses were to study the effects of simulated labs with either knowledge-of-correct-response (KCR) or answer-until-correct (AUC) feedback on students' learning compared to having no feedback. KCR directs the student to the correct answer when an incorrect answer is chosen, while AUC guides students to select the correct answer before moving on to another item, as shown in Figure 12.

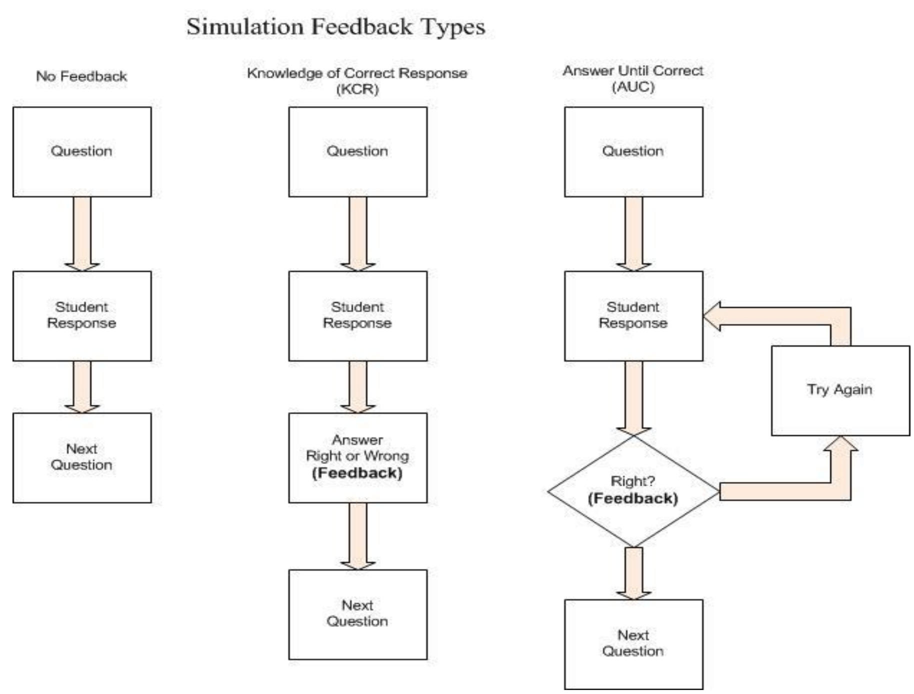

Figure 12. Feedback Types.

The first hypothesis predicted that in the learning of IT concepts, KCR-based simulated labs would be better than having no feedback. But the study did not find any significant difference between the two, which is contrary to most of the previous research reported in the literature. For example, according to Bangert-Drowns et al. (1991), KCR is superior to no-feedback; Clariana et al. (1991) observed that KCR be more effective than no-feedback; and no feedback is inferior to KCR, but it cannot be recommended as an optimum strategy (Jaehnig & Miller, 2007). Contradictory findings here may be due to the fact that the KCR feedback feature of the Packet-Tracer simulation software did not provide any explanation to the incorrect answer if chosen by the students, as established by Jaehnig and Miller (2007), "One situation in which KCR is particularly likely to be no more effective than no-feedback is when learners do not understand the material and therefore do not know why an answer is incorrect" (p. 229).

The second hypothesis predicted that in the learning of IT concepts, AUC-based simulated labs would be better than having no-feedback, and the findings did show significant im provement. Result was also consistent with the previous studies reported in the literature; for example, AUC seems effective primarily for test items (Clariana & Koul, 2006), AUC is considered to be the most effective (Bangert-Drowns, Kulik, & Morgan, 1991), and "our results support prior demonstrations that answer until correct not only assesses, but also teaches, in a manner that promotes the retention of course materials across the academic semester", reported by Dihoff, Brosvic, and Epstein (2003).

KCR or AUC?

With conflicting results regarding the effectiveness of different types of feedback reported in the literature, it is difficult to say which type of feedback is best (Clariana & Koul, 2006). For example, summarizing findings by Bangert-Drowns et al. (1991), AUC feedback is considered to be the most effective, i.e., No feedback < KCR < AUC. However, following a review of 30 studies, Clariana's (1993) findings, which are consistent with both Schimmel's (1983) meta-analysis of 15 studies and also Kulhavy and Wager's (1993) research, show KCR feedback to be equally effective, i.e., No feedback < KCR = AUC (Murphy, 2007).

One possible reason AUC feedback usually outperforms KCR in students' learning is learners' engagement, as reported by Clariana (1990): "AUC forces additional engagement with the lesson questions compared to KCR feedback. This additional engagement functions to increase the learners' depth of processing for each item by providing more information when it is needed" (p. 126). AUC effectiveness can also be attributed to its close association with the guided discovery, as such feedback is generally thought to be conducive to long-term student development; it forces students to think about their own errors and self-correction, thereby leading to increased student attention to forms and problems, while KCR feedback may not always be the optimal tool for learning from mistakes (Murphy, 2007). Therefore, when designing simulation for IT training, AUC feedback is recommended; KCR's effectiveness requires further research.

The findings of the study offer many contributions to the literature of instructional technology. First, it validates the use of simulation as an instructional strategy for teaching basic IT concepts without the support of traditional hands-on experiments, and, second, it verifies that the simulation scaffolding such as AUC feedback improves students' learning. Therefore, many traditional (and in most cases very expensive) IT labs can be replaced securely with AUC-based simulated labs for improved learning, with the added benefit of flexibility, i.e., an anytime, anywhere lab platform needed for 21st-century students.

Recommendations

The findings of the current study suggest that in order to enhance student learning, the instructional designers should consider the following:

- The use of simulation is at least as effective as hands-on labs in the learning of basic information technology concepts; therefore, when and where appropriate, traditional hands-on laboratories can be replaced with the simulated labs.
- Simulation with AUC feedback proved to be more effective than traditional hands-on labs; using such methodology will not only improve students' learning but will also offer low-cost and flexible training platform necessary for 21st-century students.
- Even though AUC is a preferable type of feedback compared to KCR, it is more complex and therefore expensive to develop.
- Instructional designers are often interested in efficiency. It might be expected that the additional steps necessary for AUC would require more study time.
- Simulation-based teaching methodology offers a cost reduction by replacing expensive physical lab equipment such as routers, switches, and firewalls. By incorporating simulation-based laboratory experiments in place of physical laboratories, institutions can save a tremendous amount of expenditure.

- Simulations offer flexibility in terms of anywhere, anytime learning. Being able to access the software online can benefit both onsite and offsite students equally.
- Students' knowledge of simulation programs is one of the major factors for enhancing their learning experiences. Necessary software training should be provided before it is used as a learning platform.
- Simulation based labs offer a safe working environment for learners. In a traditional lab, a typical station has high voltage connections and outlets to run IT equipment such as routers and switches, potentially creating a hazardous environment. Simulation, on the other hand, has no such threats.

Future Studies

- In order to establish further reliability and validity of the current findings, similar studies should be conducted in other programs such as telecommunications, wireless networks, fiber optic networks, instrumentations and controls, etc.
- This study used a small (20) sample size. It is suggested that future studies use a larger (>30) sample size to validate the results obtained in the present study.
- This study used student test scores as the primary factor for determining student learning. Test validity issues can adversely affect the reliability of measuring student learning. Future studies should incorporate other methods such as assignments, lab projects, etc. to increase reliability of measuring student learning.
- This study only dealt with network cabling systems. It is recommended that similar studies should be conducted for other IT areas such as routers, switches, firewalls,

packet analysis, etc. to develop a complete understanding of the effectiveness of simulation on student learning in the area CCNA training.

- This study used tests designed by only one instructor. For future studies, tests and quizzes should be designed by multiple instructors to enhance the content validity and reliability of the testing instruments.
- This present study dealt with a student group that represented recent high school graduates who were mainly Caucasian. Future studies should consider other factors such as gender, ethnicity, age, and related work experience. Incorporation of such factors would further validate the findings.
- Knowledge retention as a learning goal was not considered in this study. Future studies should consider evaluating the effects of simulation with or without any feedback on learners' ability to retain the knowledge.

Conclusion

The purpose of this quantitative study was to explore the impact of the use of computer simulation's feedbacks such as knowledge-of-correct-response (KCR) and answer-until-correct (AUC) on students' declarative knowledge in the area of information technology, i.e., computer networking and infrastructure.

The findings based on quantitative analyses verified that the simulation-based instructional strategies are at least as effective as hands-on teaching methodologies for the purpose of learning of IT concepts. These findings were consistent with the studies reported in the literature. On the other hand, the study failed to validate the superiority of simulation over hands-on labs; therefore, further research is needed.

Previous studies regarding AUC that it might be an optimum form of simulation feedback has been verified. KCR feedback effectiveness, on the other hand, cannot be validated; hence the recommendations for future research.

Participants of this study were mainly high school graduates who were novices in the field of computer networking and also had a limited experience with Packet-Tracer simulation software. Future researchers should consider these and other factors such as ethnicity, age, and gender to further validate the findings.

One of the key attributes of any guided discovery learning is scaffolding, and feedbacks as an essential component of scaffolding deserves serious attention. The result of this study provided insight on the effectiveness of different types of feedback when used in a simulated environment. These results should help instructional designers to engineer better learning platforms in terms of their effectiveness.

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APPENDIX A

ACRONYMS

Acronyms

Crossover Cable	A cable with connections that “crossover” used to connect two devices of the same type: two hosts or two switches to each other
BGP	Borger Gateway Protocol
DNS	Domain Name Service
EIGRP	Enhanced Interior Gateway Routing Protocol
Ethernet	Computer networking technologies for Local Area Network
HTTPS	Protocol for secure communication over a computer network
IP	Internet Protocol, carries user data
LAN	Local Area Network
OSPF	Open Shortest Path First, for dynamic routing
PING	Command to test connectivity
RIP	Routing Information Protocol for dynamic routing
RJ-45	A connector standard for computer cables
Router	Device to interconnect networks i.e. LAN\WAN
Serial DTE	Serial cable that does not supplies the clock signal
Serial DCE	Serial cable that supplies the clock signal pacing the communications on the bus
STP Cable	Shielded twisted pair cabling is a type of wiring in which two conductors of a single circuit are twisted together for the purposes of canceling out electromagnetic interference (EMI) from external sources
Straight-Through Cable	Type of twisted pair copper wire cable for local area network (LAN) use for which the RJ-45 connectors at each end have the same pin-out (i.e. arrangement of conductors)

APPENDIX B

INSTRUCTIONAL AND ASSESSMENT ITEMS

Survey

Class Session (circle one): Morning Evening Night Weekend

1) When did you complete NETW 203 course?
a. Not completed b. Within last 6 months c. Within last 12 months d. More than a year

2) How long you have been working with computers?
a. Less than a yr. b. More than a yr. c. More than 2 yrs. d. More than 5 yrs.

3) Are you currently employed in computer networking area?
a. Yes b. No

4) Are you a full-time student?
a. Yes b. No

5) Do you have any preferences when it comes to completing a lab work?
a. Hands-on b. Simulation c. No preference

6) Have you ever used any simulation software for training?
a. Yes b. No

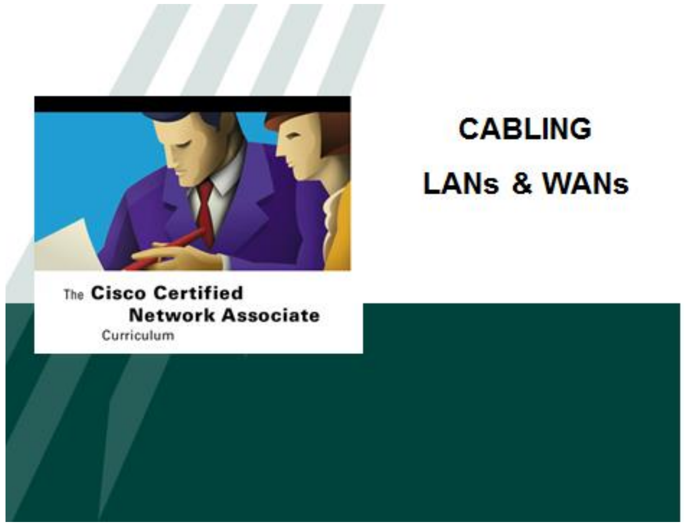
7) How much experience do you have with the Packet Tracer?
a. None b. Little c. Comfortable d. Expert

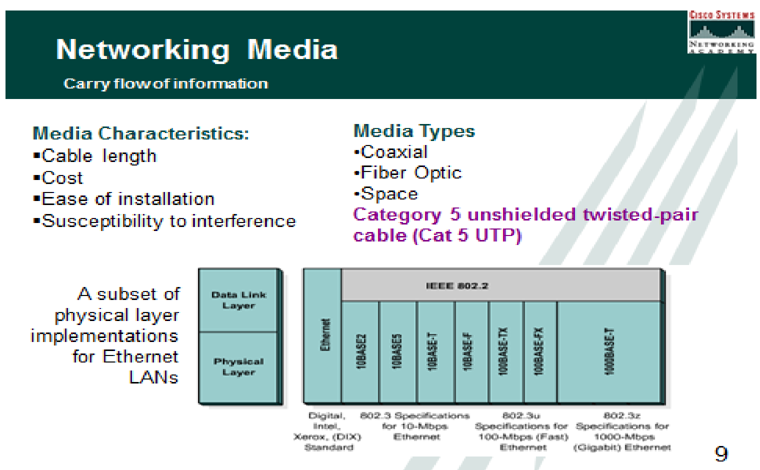
8) Do you have any experience wiring networking devices (routers, switches, etc.)?
a. Yes b. No

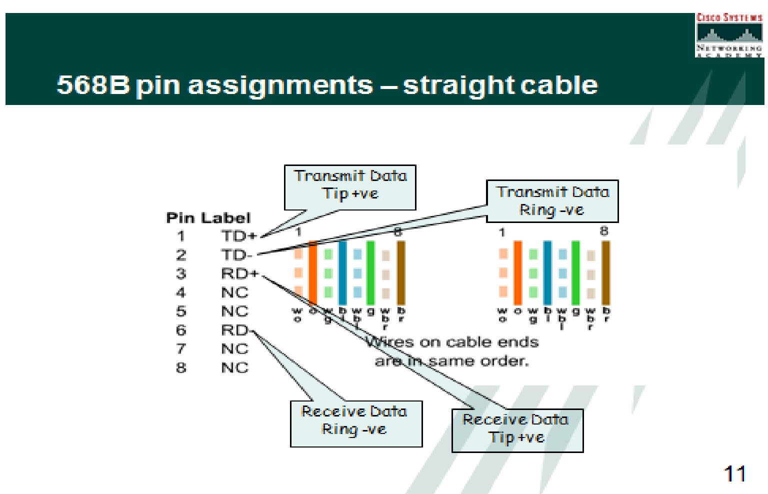
9) Are you planning to take CCNA exam within next 12 months?
a. Yes b. No

10) Are you familiar with RJ45?
a. Yes b. No

Short Lecture PowerPoint Slide Samples



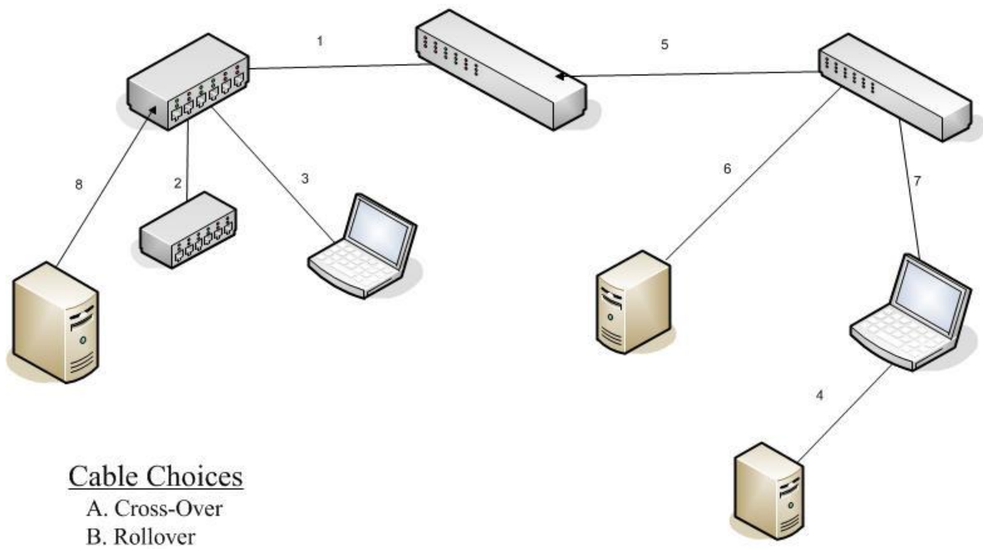




Pretest

Pre-Test
In the following network diagram, identify the type of cables required.
(Pick from the seven choices provided below)

Group:_______



Answers

1:_________

2:_________

3:_________

4:_________

5:_________

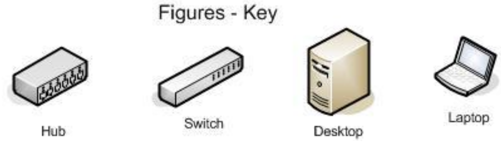
6:_________

7:_________

Cable Choices

A. Cross-Over
B. Rollover
C. Serial DCE
D. Serial DTE
E. Straight
F. Twisted Pair
G. UTP

Figures - Key



Simulated Lab

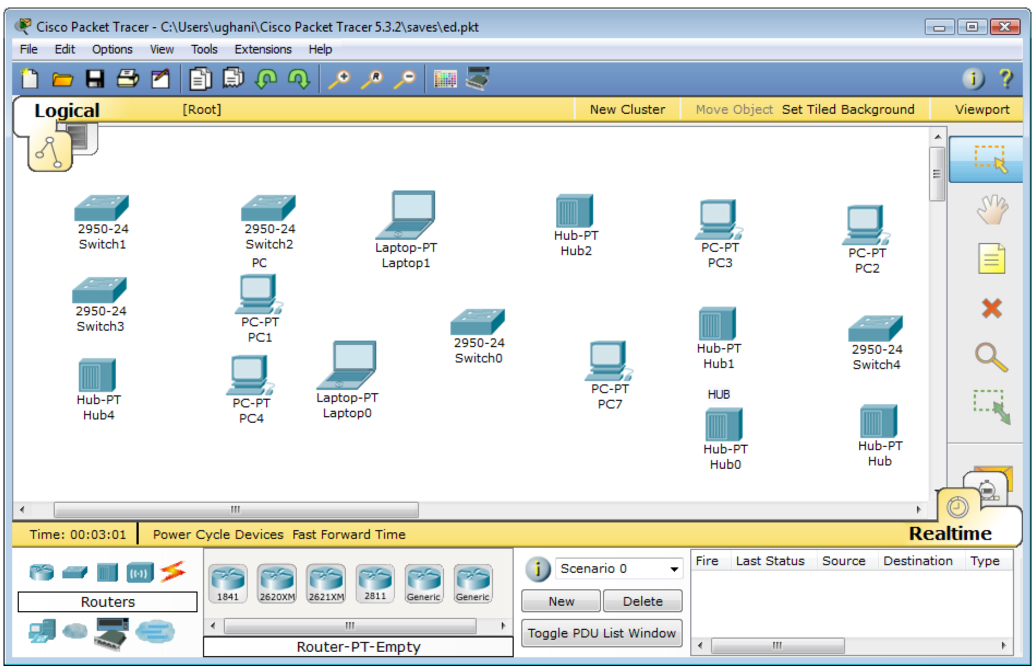
Lab Experiment
Time Allowed: 20 minutes

Name:______________________

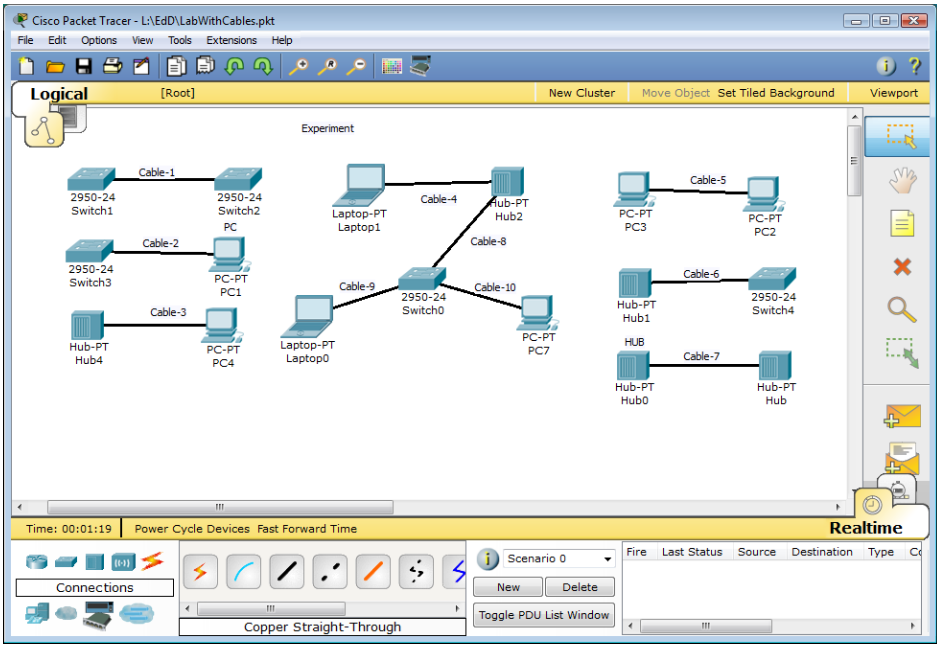
Group: ____________

Instructions:

1. Logon to the computer using your account
2. Start Simulation Software (Cisco Packet Tracer)
3. Browse F:\Ghani folder and locate 'exp.pkt' file
4. Open the file 'exp.pkt' by double clicking
5. You should see the networking equipment as shown below



6. Start interconnecting these devices from the pool of available cables (see diagram below). You may need to experiment with different cables before finding the right one.



7. After interconnecting all the devices as shown, copy below the type of cable have chosen for each link

Link	Cable Type Selected
Cable-1	
Cable-2	
Cable-3	
Cable-4	
Cable-5	
Cable-6	
Cable-7	
Cable-8	
Cable-9	
Cable-10	

8. Close Packet-Tracer
9. Logout from the computer
10. Make sure you have filled out your name and group # above
11. Turn-in all three pages
12. Ask the researcher if you can leave the room

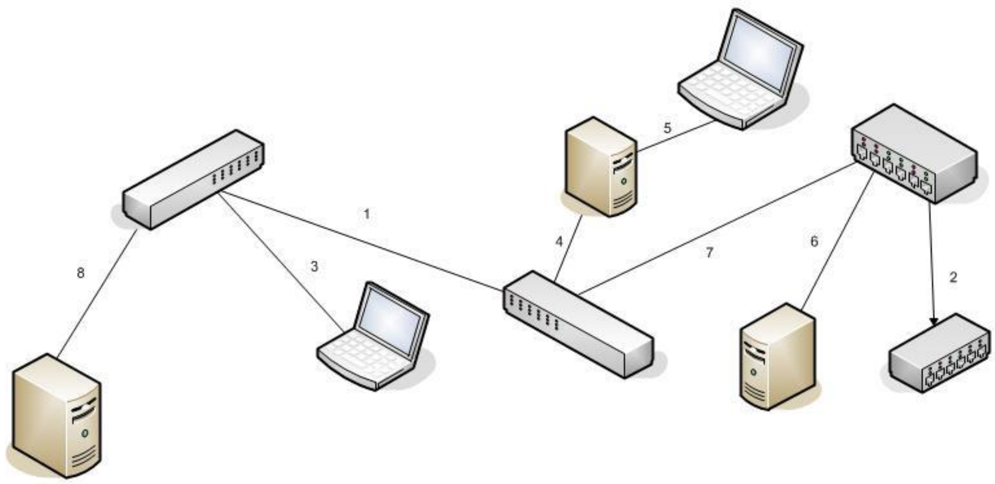
Thank you for your participation!

Posttest

Post Test

In the following network diagram, identify the type of cables required.
(Pick from the seven choices provided below)

Group:_______



Answers

1:________

2:________

3:________

4:________

5:________

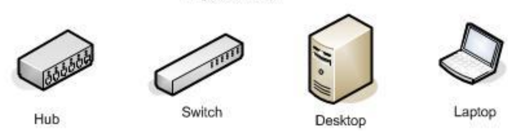
6:________

7:________

Cable Choices

A. Cross-Over
B. Rollover
C. Serial DCE
D. Serial DTE
E. Straight
F. Twisted Pair
G. UTP

Figures Key



APPENDIX C

CONSENT FORM

Research Study Consent Form Feedbacks in Simulated Lab Environment (Optional)

Name: ___________________________________

Hello Participant,

This study is an attempt to understand the connection between the way feedback are presented in a simulated lab environment and the learning outcome (declarative knowledge). Because this study will utilize a small number of participants your responses carries a great deal of importance. Please be completely honest during this study, even if you have something negative to say. Be assured that your answers will remain confidential. Please read and sign the consent form below, if you agree to participate in the study.

I agree to participate in the research project involving the use of simulated\hands-on lab being conducted by Mr. Usman Ghani, a faculty member of DeVry University under the direction of Dr.Wei-Cheng Hung a faculty member of Northern Illinois University (NIU). I have been informed that the purpose of the study is to investigate the connection between feedback-types and declarative knowledge.

I hereby certify that I am at least 1 8 years of age and enrolled in NETW205 course at Devry University as a part of my CCNA training. As a participant in this study,1 will be asked to complete a pre-test, perform an experiment, and to take a posttest. The whole session will take about an hour.

I am aware that my participation is voluntary and may be withdrawn at any time without penalty or prejudice and if I have any additional questions concerning this study, I may contact Mr.Ghani at (630) 890-5828 or Dr.Wei-Cheng Hung at (81 5) 753-8175. Any questions concerning my consent and rights with respect to this study can be directed to Office of Research Compliance, Northern Illinois University, at (815) 753-8524.

I understand that there are no intended personal benefits of this study and that participation or non-participation in this study and the results from any instruction contained therein have no connection to any courses or degree programs at DeVry University.

I have been informed that there are no known risks and/or discomforts that I could potentially experience during this study. I understand that all information gathered during this study will be kept confidential and will not be disclosed publicly. I further understand that this study will only summarize the results of groups of participants and will not disclose any results about me personally.

I understand that my consent to participation in this project does not constitute a waiver of any legal rights, and I acknowledge that I have received a copy of this consent form.

___________________________ ______________________
Signature Date