Effect of feedback mechanisms on students’ learning in the use of simulation-based training in a computer engineering program

Usman Ghani

ABSTRACT
Feedback is a vital element for improving student learning in a simulation-based training as it guides and refines learning through scaffolding. A number of studies in literature 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. Thus, emulating these adaptive aspects of human tutoring in simulation provides an effective methodology to train individuals. This paper presents the results of a study that investigated 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 are also examined. The paper presents the summary of findings based on quantitative analyses, which reveal 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 paper also compares the results of the study with the earlier studies and recommends strategies for using feedback mechanism to improve students’ learning in designing and simulation-based IT training.
I. INTRODUCTION
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. 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 has become more prevalent in the field of instructional technology is simulation. The focus of this paper 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.

The educational institutions are continuously being challenged to offer flexible learning platforms. According to Bell, Kanar, and Kozlowski, “a number of emerging challenges—such as economic pressure, globalization and work-life issues—have combined to create a business environment that demands innovative flexible training solutions”. From distance education to online learning, and from portable gears to simulations, all are parts of the same effort to establish flexible learning environments. 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.

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., “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”. According to Sancristobal, Castro, Martin, and Tawkif 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: “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”. 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, and such immersion can enhance learners’ feeling of presence, or the perception of actually being in a particular environment. Such real-world settings can in turn contribute to prompting psychological processes that are responsible for improving performance characteristics.

II. IMPORTANCE OF 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. 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. 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. 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 whether 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).

III. 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. Narciss 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”11. According to Moreno, “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”12.

One way to better understand the effect of simulated activities on students’ learning is to expand the research to uncommon educational areas such as 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. The following are the research questions:

1. 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.

2. Do KCR (knowledge-of-correct-response) feedback features of simulated labs in CCNA programs 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.

3. Do AUC (answer-until-correct) feedback features of simulated labs in CCNA programs 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 programs will produce improved declarative knowledge (as reflected in the differences between pretest and posttest scores) more than the hands-on activities.

4. Do KCR (knowledge-of-correct-response) feedback features of simulated labs in CCNA programs 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.

5. Do AUC (answer-until-correct) feedback features of simulated labs in CCNA programs 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.

IV. DESCRIPTION OF STUDY

The sample represents the study comprised of 80 students enrolled in four sections of the Cisco Routing Fundamentals (NETW205) course offered during the winter session of 2012, at DeVry University, Addison, Illinois 60101. 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-lab 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 are illustrated in Table 1. Computer network simulation software known as ‘Packet-Trace’ from Cisco Systems was used to conduct the study. Packet-Tracer’s screen shot is illustrated in Figure 1.
V. DATA ANALYSIS
Quantitative findings:
Participants: The sample size consisted of 80 participants; 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, i.e. 20 members per group: 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 the AUC group demonstrating the largest standard deviation (SD = 5.59). The data were analyzed using a statistical package known as Statistical Package for the Social Sciences (SPSS). 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 deviations were examined for the purpose of drawing any meaningful conclusions.

VI. FINDINGS
Laboratory exercises play a key role in the education of future scientists and engineers, yet there exists disagreement among science and engineering educators about the effectiveness and types of technology-enabled laboratory exercises to be used. The present study was designed to address this
concern. 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. “There was no significant difference in lab test scores when experimenting with either simulation or hands-on physical equipment.” 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 does 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 does 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 does 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 does 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 does produce better results than the simulated labs with no feedback when it comes to improving declarative knowledge in the learning of basic IT concepts.

VII. IMPLICATIONS FOR PRACTICE: RECOMMENDATIONS

The findings of the current study suggest that in order to enhance student learning, the instructional designers should consider the following recommendations for incorporating simulation and feedback in the design of curricula:

- 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 a low-cost and a flexible training platform.
- 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.
- 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.

VIII. CONCLUSION

The paper presented the results of a quantitative study designed 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. The results of previous studies, suggesting that AUC might
be an optimum form of simulation feedback, have been verified. But on the other hand, the effectiveness of the KCR feedback could not be validated by the present study.

REFERENCES


