Board 23: The Effects of a Mobile Learning Environment on Stident Achievement in a Circuits Analysis Course

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THE EFFECTS OF A MOBILE LEARNING ENVIRONMENT TUTORING SYSTEM ON STUDENT ACHIEVEMENT IN A CIRCUITS ANALYSIS COURSE

Abstract— **This research study examined the effects of using a mobile learning environment (MLE) based tutor that provided scaffolded assistive tutoring on student achievement in a Circuit Analysis (Network Theory) course. Eighty-three college students were randomly assigned into one of three groups and participated the study for an entire semester. Scores from three examinations were recorded from all students throughout the semester. Multilevel longitudinal modeling was used to assess effects of the MLE on student exam scores over three examination periods. The combined experimental group (*n* = 37) showed statistically significant increases in mean student achievement over the control group. This research proposed that MLE-based digital tutors have the potential to connect anywhere, anytime learning with domain-specific information and provide students with instructional strategies that scaffolds learning.** **(***Abstract***)**

Keywords—MLE, ubiquitous, domain-specific, scaffolding

Introduction

Degrees in engineering awarded by US universities to US citizens dropped by 23% over the past decade [1]. One specific reason for this decline can be attributed to dropout rates. According to Belasco [2], 60% of students in engineering drop out or change their major in the first year, due to a gateway course known as Circuit Analysis (Network Theory). Murata [3] suggested that a lack of metacognitive skill could account for learners' inability to reach correct answers in spite of basic knowledge mastery of circuit theory. Scaffolding assists in increasing metacognitive performance by providing direction to cognitive strategies through strategic support for students as subject mastery increases [4]. Learning scaffolds are instructional guides or prompts provided during problem-solving that attempts to close the gap between a novice learners' current state of understanding and an experts' body of domain-related knowledge [5]. Research has shown the effectiveness of scaffolding strategies employed in digital cognitive tutors through academic achievement or growth rates [6, 7]. In this experimental study, a digital assistive tutoring application was developed to assist in increasing student achievement and problem-solving performance for undergraduate students enrolled in a Circuit Analysis course. This was achieved through the application's embedded performance-based scaffolding and full-step solutions.

Background

Theoretical Frameworks

The Model of Contingent Instruction [8, 9] and Metacognitive Support [10] served as theoretical frameworks in this research study. The Model of Contingent Instruction functioned as the method of delivery for the performance-based scaffolds in the MLE tutor. The Model of

Metacognitive Support functioned as a rubric for scaffold formulation and implementation in the MLE-based tutor. At each level of scaffold delivery, information provided to the student represented a problem-solving phase that prompted students to access an associated metacognitive function. Scaffolding is the process involved in the expert to novice exchange of information that allows the novice to complete a task that was initially beyond the novice's current level of understanding [11]. Research shows that the use of scaffolds allows students to actively engage difficult lesson objectives that, without the instructional scaffolds, may not be possible in different settings [12, 13]. Scaffolding, in problem-solving, attempts to move the learner's domain knowledge from novice to expert throughout the learning objective [14, 15].

Cognitive tutors in Circuit Analysis

According to Chi [16], the definition of expertise is the "possession of a large body of knowledge and procedural skill". They further state that intelligence is the ability to use their knowledge space efficiently and reduce time on task. In addition, Dufrense [17] suggested that differences in novice and expert performances in a variety of domains can be "attributed to the rich, interconnected body of domain-specific knowledge possessed by experts". This suggests that novices, with the guidance of expert assistance, may be able to transition to expert cognitive structures situated within specific domains. However, Ertmer [18] suggest that the expert-novice difference is not a consequence of knowledge and skill inadequacy, but rather the "inability to implement regulatory strategies when students become aware that certain facts or skills are missing from their learning repertoires that are necessary for reaching desired goal."

Research studies have suggested that when digital cognitive tutors are used in conjunction with formal instruction, they can promote self-regulated learning (SRL) and the personalization of the learning process making students aware of their learning goals [19-21]. Recent research conducted on cognitive tutors or a class of cognitive tutors called intelligent tutoring systems (ITSs) have shown the effectiveness of these digital platforms at increasing student achievement and problem-solving performance in Circuit Analysis (Network Theory) courses [22-26]. In addition, some studies have produced increased metacognitive ability and knowledge construction while gaining domain-related knowledge in Circuit Analysis (Network Theory) courses [17, 27-29].

This research study implemented a circuit tutoring system with performance-based scaffolding enabling a connection between learned theory and specific application. CircuitITS (CITS) and Circuit Test Taker (CTT) were developed as circuit analysis tutoring systems designed to enhance learners' metacognitive strategies for solving electrical circuit problems supplementary to classroom instruction. Figs. 1-4 show CITS subject selection and performance-based scaffolding screens.

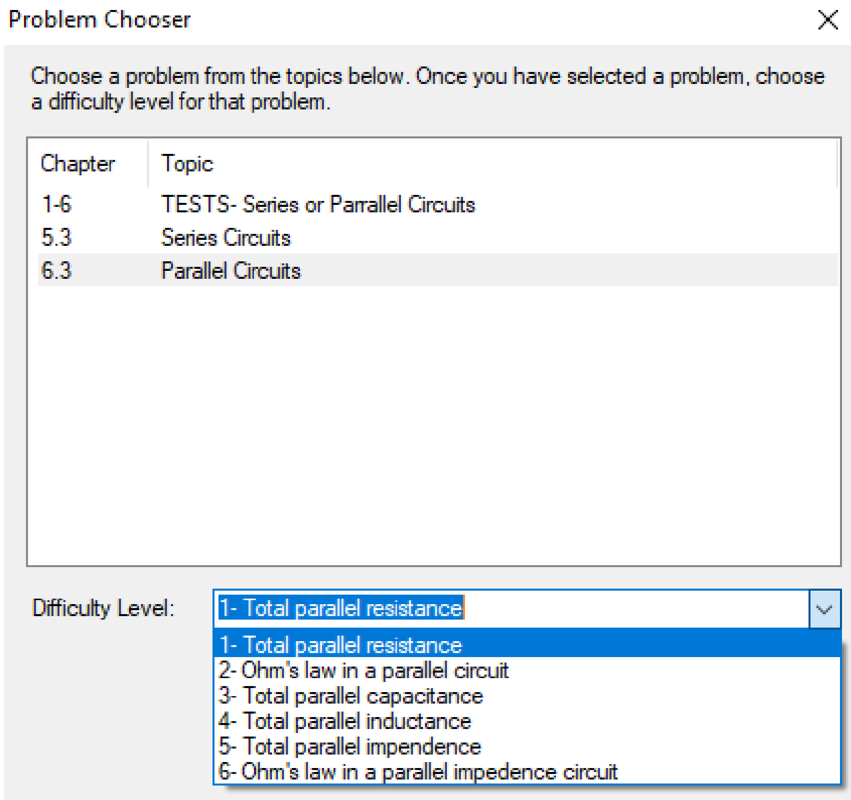

Fig. 1: Subject selection screen

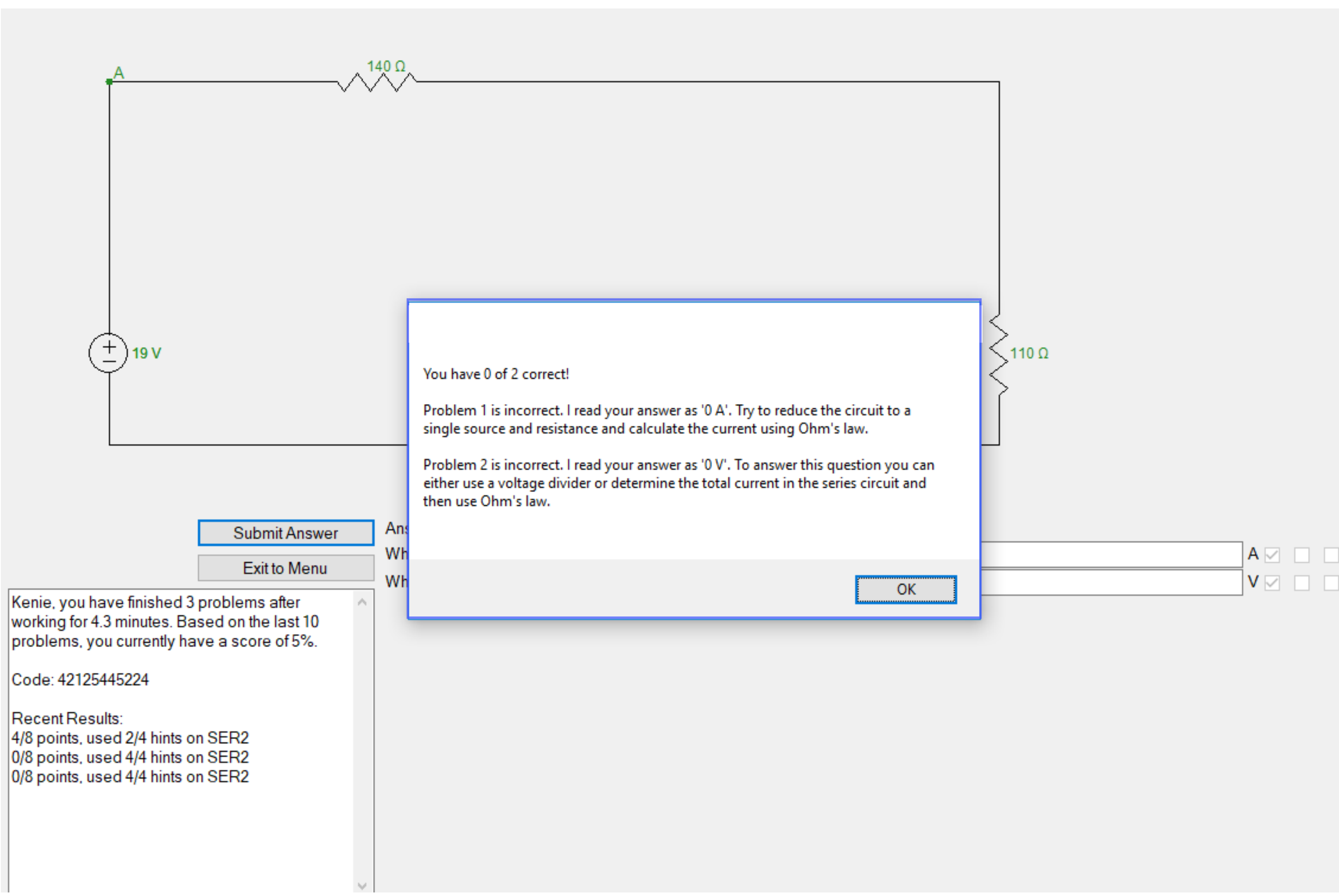

Fig. 2: CITS 1st level performance-based scaffold

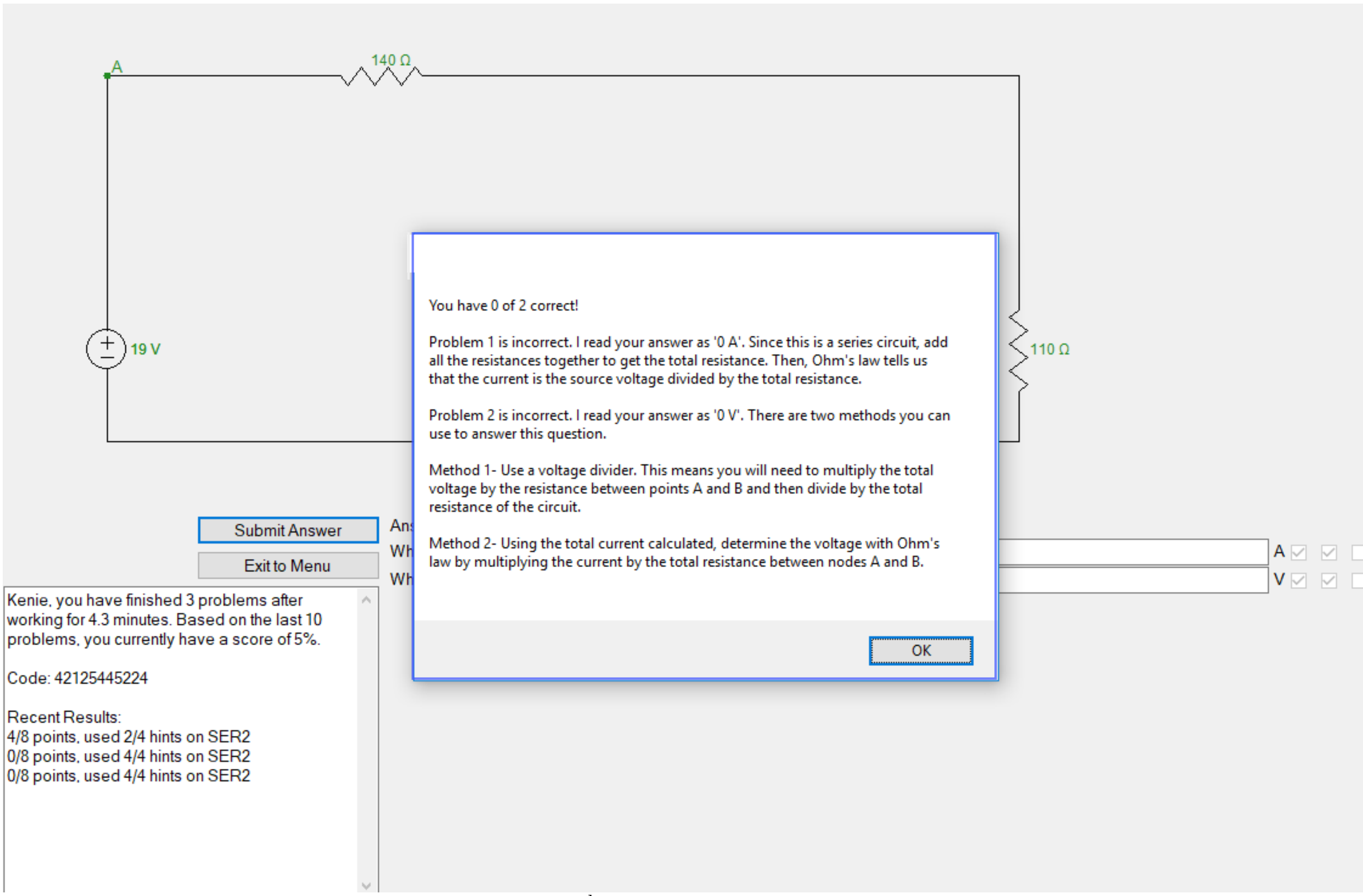

Fig. 3: CITS 2nd level performance-based scaffold

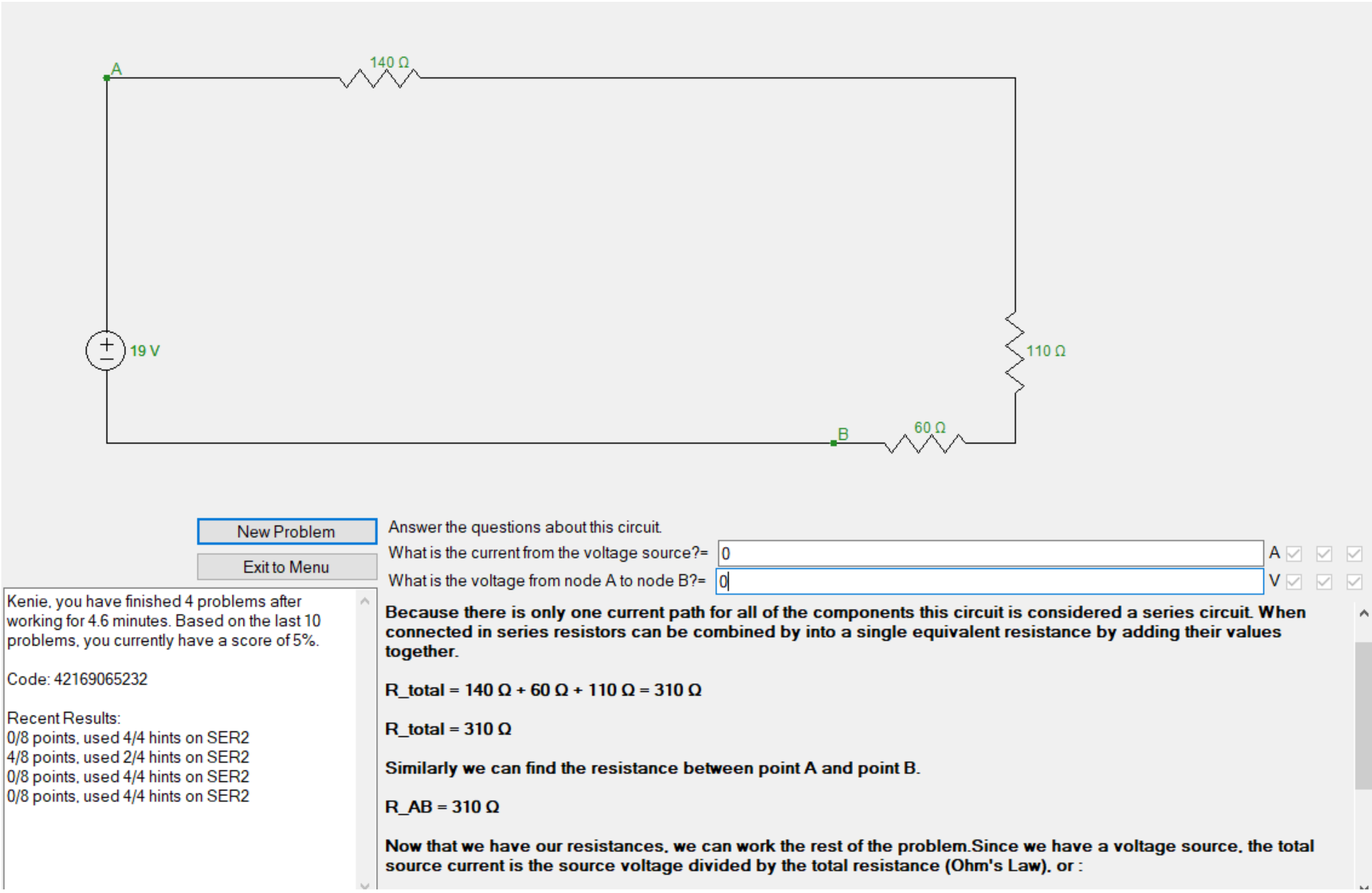

Fig. 4: CITS bottom-out solution

The CITS tutoring system promotes the activation of previous knowledge in the learner by providing prompts or scaffolds to the learner if they answered the problem incorrectly. This prompt feedback and assistive technique is three-tiered increasing in the strength of the scaffold or prompt if the learner continues to answer the problem incorrectly resulting in a “bottom-out” solution of the problem. With the CITS tutoring system, the user is not limited by system constrained problems. Based on the user-selected subject, they system generates problems associated with subject selection and student-attempted problems never contain the same values and are different in circuit topology. The CTT tutoring system is a test-taking only tutoring system that provides full-step solutions to all items missed at the completion of the simulated exam. In addition, both versions of the MLE tutor collected interaction data such as duration of use, frequency of use, the and the level of difficulty of problems solved when using the tutors.

Current Study

The purpose of this experimental research study was to examine the effects of an instructional intervention on students’ learning outcomes when solving electrical circuit problems. Moreover, this study examined if performance-based scaffolding delivered in an MLE-based tutoring system increased student achievement and problem-solving performance. In addition, this study sought to examine if there were differences in treatment effects between the CircuitITS (CITS) and Circuit Test Taker (CTT) interventions. Participants were eighty-three (83) undergraduate students enrolled in a Circuit Analysis (Network Theory) course at a Midwest public research institution in Illinois.

This research study aimed to answer the following questions:

a) Did exam scores of students who use Circuit Test Taker or CircuitITS differ from the scores of students who do not receive an intervention?
b) Did exam scores of students who use the Circuit Test Taker differ from those who use CircuitITS?
c) Among students using CircuitITS, to what extent did the number of scaffolds elicited predict student exam score performance?

Study Procedures

One section of students (n = 87) enrolled in an advanced Circuit Analysis (Network Theory) course were randomly assigned (n = 37) to one of the two treatment groups (CITS or CTT). Due to student course drops, subsequent sample size was adjusted to (n = 83) students. Students that elected not to utilize the MLE tutors were assigned to the Control group (n = 46). Over the course of a semester, students were encouraged to engage with the MLE tutors when studying and in their spare time. Three midterm examinations were administered to all students enrolled in the course over the duration of the semester in the Spring of 2018.

This study's research design was a multilevel three-midterm examination structure that compared participant and control groups to assess changes in student achievement. This study's structure consisted of a longitudinal framework that utilized multilevel modeling to investigate the relationships among this study's implementation of an MLE tutor and students' achievement in an advanced Circuit Analysis (Network Theory) course. Multilevel modeling was the specific research design for this study because participants' data existed at multiple levels [30, 31].

Access was granted through the College of Engineering after consent was given by the department. Two versions of the MLE tutoring system were developed and implemented. Version one, CircuitITS (CITS), provided two-tier performance-based scaffolding with a "bottom-out" answer that presented customized text showing the step-by-step solution. In addition, CircuitITS also provided integrated testing assessments with full solutions at the end of the assessment. Version two, Circuit Test Taker (CTT), was also deployed and allowed students to engage in the same testing mechanisms as CITS with full solutions at the end of the assessment but did not provide performance-based scaffolding. Both systems provided unlimited problem variation and allowed for testing with feedback, but only CITS provided performance-based scaffolding.

Study Results

RQ1

The first research question investigated the effects of either version of the MLE tutor on student achievement. More specifically, the first research question investigated if either version of the MLE tutor differed from the control condition not receiving any intervention. A multilevel means-as-outcomes model showed a statistically significant, positive effect of the use of both the CTT intervention (β_{01} = 4.67; $p < .01$) and CITS intervention (β_{02} = 4.17; $p < .05$) on student exam scores (where β_{01} and β_{02} are the effects of the CTT and CITS interventions on student exam scores, respectively). Specifically, students who utilized either the CTT or CITS intervention scored higher than students who did not utilize any intervention (control group) with the proportion of the exam score variance explained by the combined intervention (R^2 = .165) and medium to large effect size ($r > .30$), according to Cohen [32].

RQ2

The next research question sought to examine if there were significant differences between the two types of interventions. More specifically, this research question examined if CITS or CTT differed in their contribution to student achievement. The control group cases were not used in this analysis. Results from a multilevel means-as-outcomes model showed no statistically significant differences in exam scores between the CTT (β_{01}= .51; $p < .05$) and CITS (β_{01} = .47; $p < .05$) interventions. In other words, both tutors performed at nearly the same level.

RQ3

The final research question sought to examine if the number of hints or scaffolds utilized predicted student achievement. More specifically, this research question sought to examine if students' exam scores, among those who utilized the CITS intervention, were related to CITS's performance-based scaffolding mechanism. The control group cases were not used in this analysis. Results from a multilevel random effects ANCOVA model showed a significant positive effect of the scaffolding predictor (β_{20} = 1.54; $p < .05$) on student exam scores across time (where β_{20} is the effect of the scaffolding predictor on student exam scores) with the proportion of the variance explained by the scaffolding predictor (R^2 = .158) and medium to large effect size.

Discussion and Conclusion

This study examined the effects of an MLE-based tutoring system on student achievement and problem-solving performance in an advanced Circuit Analysis (Network Theory) course. Undergraduate students enrolled in the course were assigned to either the treatment or control groups with the treatment group utilizing one of the two versions the MLE-based tutor, CircuitITS (CITS) or Circuit Test Taker (CTT). The CITS and CTT intervention groups both received testing and feedback within the tutors, but only the CITS intervention group received performance-based scaffolding. Results indicated that there was a positive significant difference between the control group and the intervention group as a whole (CTT & CITS) and as individual interventions (CTT or CITS). CITS and CTT performed equivalently or better than results gathered from other ITS implementations by increasing mean student achievement in a range of 13% to 19% over the course of a semester measured by multilevel statistical analysis over three semester exams. Furthermore, performance-based scaffolding implemented in the CITS tutor was shown to significantly contribute to increased student achievement by as much as 5% over the course of the semester.

There have been a number of research studies documenting the positive effect of mobile learning on student achievement [7, 33-37]. These studies provide empirical evidence that mobile learning in the context of their respective domains can increase domain-related knowledge and student achievement. According to Demir [38], researchers face extreme difficulty in conducting longitudinal studies with mobile learning. They further state that this could be due to the control of variables and the acquisition of viable interaction data. However, research conducted by Tabuenca [39] or Moses [40] demonstrated that longitudinal research conducted with the use of MLEs or MLE-based tutoring systems can produce positive effective results when used in conjunction with university-approved course curricula. Furthermore, user interaction data could be captured internally and transmitted to a database-linked server that could process the data for learning analytics.

This research study's results has implications for developers of digital tutors and instructors coordinating engineering programs. It provides empirical evidence that an ITS implemented in MLE architecture adds value to students' learning outcomes in an advanced Circuit Analysis (Network Theory) course. In this research study, CITS and CTT was able to significantly increase student achievement over the course of the semester [54]. Differentiated from previous research, CITS and CTT have the potential to extend learning beyond the assigned lecture book problems by providing students with the opportunity to work an unlimited number of problems. Furthermore, this MLE-based cognitive tool can aid students in increasing academic achievement and problem-solving ability. No longer are students constrained to only problem-solving from their textbook. Digital tools of this architecture can assist students in and outside of the classroom and on a variety of mobile platforms. These results provide significant implications for the field by providing a data-driven, evidence-based solution for administrators and instructors to optimize instructional strategies, integrate emerging technological tools and facilitate anywhere-anytime learning for the ubiquitous learner.

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