Board 24: The Effects of Mobile Circuits Tutor on Students' Problem-solving Self-efficacy and Anxiety

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THE EFFECTS OF MOBILE CircuitITS TUTOR ON STUDENTS' PROBLEM-SOLVING SELF-EFFICACY AND ANXIETY

Abstract— **This research study investigated the effects of an assistive mobile learning environment (MLE) on students' self-efficacy and anxiety of problem-solving. Eighty-three college students were randomly assigned into one of three groups and participated the study for an entire semester. The control group did not have access to the app. Participants were split into two treatment groups based on one of the two versions of the MLE tutor (CircuitITS or Circuit Test Taker). Scores from three examinations were recorded from all students throughout the semester. The combined experimental group were asked to complete scales measuring self-efficacy and anxiety at three time points that coincided with midterm examinations. Multilevel longitudinal modeling (MLM) was used to assess the effects of the assistive MLEs on problem-solving self-efficacy and anxiety. MLM was also used to assess effects of problem-solving self-efficacy (NTSEI) scores and problem-solving anxiety (PSA) scores on student examination scores. Results showed a significant negative effect of CircuitITS on NTSEI scores but a positive significant effect of NTSEI scores on exam scores for both tutors. This research study provides results that are counterintuitive to the proposed outcome suggesting that CircuitITS produced a reduction in problem-solving self-efficacy among its users. Although students who utilized CircuitITS experienced a decreased perceived ability to problem solve, both tutors showed significant increases in examination scores.** (*Abstract*)

Keywords—mobile learning environment, self-efficacy, metacognitive support

Introduction

Circuit Analysis (Network Theory) is fundamental "gateway" course that most engineering students must take as part of their engineering curriculum and is also a course that has the highest attrition rates among engineering courses [1, 2]. High attrition rates contribute to an increase in dropout rates and according to Belasco [3], 60% of students enrolled in engineering courses drop out or change their major in the first year. There are a number of causes engineering students drop out or change their major, but a specific course has been found to cause the most trouble, Circuit Analysis (Network Theory). Murata [4] suggested that, when performing circuit analysis, a lack of metacognitive ability could explain why learners exhibit an inability to reach correct answers despite mastery of basic engineering fundamentals. Moores [5] suggested that metacognition involves one's ability to monitor and control their thought processes and similarly self-efficacy involves one's ability to organize and execute given tasks. Developing metacognitive skill may increase the effectiveness of the learner performing problem-solving activities [6, 7].

A number of research articles have suggested decreased metacognitive ability could be attributed to students' (affective domains) high anxiety and low self-efficacy [5, 8, 9]. According to Vitasari [9], students with high anxiety experienced decreased cognitive function with difficulties in

memory recall and information management. Students experiencing symptoms of low self-confidence and low self-efficacy could reduce commitment to their chosen degree resulting in course attrition [9, 10]. Efforts to create learning environments and learning applications to mitigate high attrition rates and assist in engineering fundamentals are wide spread and well-known and have been successful in implementation with high significance [11-15]. However, very few research studies have implemented learning environments or applications for Circuit Analysis (Network Theory) in mobile architectures for higher education. Even fewer have examined affective domains with MLE-based tutoring systems and their effect on student achievement. This study explores how an MLE-based tutoring system was implemented to increase academic achievement and its effect on students' affective domains in an advanced Circuits Analysis (Network Theory) course.

Background

The motivation for this study centers around the high attrition rates of undergraduate students in Circuit Analysis (Network Theory) courses. The overall research study was conducted with the premise that the introduction of an assistive app that provides tutoring of Circuit Analysis (Network Theory) problems would increase student achievement and problem-solving self-efficacy while decreasing anxiety. Self-efficacy as it relates to metacognitive performance in problem-solving is a function of a student's ability to recognize, organize and execute mental subroutines that are present when problem-solving [5]. The mental monitoring that is present in metacognition is similar to an individual's beliefs in their problem-solving self-efficacy. According to Kapa [16], successful problem-solving is achieved according to metacognitive function. The Model of Metacognitve Support provides students a meta-strategy for the activation of analysis, monitoring and control processes in successful problem-solving. Similarly, research has shown that students with high anxiety experience a decreased sense of self-efficacy and academic achievement [17-19]. By increasing students' metacognitive knowledge and learning strategies through "treatment", the resultant outcome would have an "ameliorative effect on anxiety." [20]

Cognitive tools and Metacognitive ability

According to research, cognitive tutors attempt to optimize learning and produce cognitive skills that assists students in the acquisition of domain knowledge [21]. Not only do they increase cognitive skill, but they promote self-regulated learning (SRL) of which factors such as "motivations, beliefs" and self-efficacy influence metacognitive ability [22]. Furthermore, they have the ability to increase student achievement and provide "context-specific instruction when students need it." [23]

Previous research has shown the effectiveness of cognitive tutors in learning contexts [24-29]. They have been effective in institutions spanning elementary to post-secondary education in a variety of learning disciplines. Of the learning disciplines, Circuit Analysis (Network Theory) poses one of the greatest challenges for novice learners in engineering. Research conducted by Moses [30] demonstrated that MLE-based digital tutors increased student achievement by as much as 13% to 19% in an advanced Circuit Analysis (Network Theory) course. One version of the the MLE-based tutor, CircuitITS, featured per-problem performance-based scaffolding, test-taking functions and solution feedback. The tutors, 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.

Current Study

The purpose of this experimental research study was to examine the relationship between an instructional intervention and students' learning outcomes, self-efficacy and anxiety. Moreover, this study examined if an MLE-based tutoring system affected students' self-efficacy or anxiety and if those affective domains impacted student achievement. Participants involved in this part of the study were undergraduate students enrolled in an engineering course at a public research institution in Illinois.

This research study aimed to answer the following questions:

a) Did the use of CITS or CTT predict students' problem-solving self-efficacy or anxiety?

b) Among students who used CITS or CTT, was problem-solving self-efficacy or anxiety related to students' exam scores?

Study Procedures

One section of students (n = 37) enrolled in an advanced Circuit Analysis (Network Theory) course were randomly assigned to one of the two treatment groups (CITS or CTT). Over the course of a semester, students were encouraged to engage with the MLE tutors when studying and in their spare time. Three course examinations and three surveys were administered to intervention groups' participants enrolled in the course over the duration of the semester in the Spring of 2018. Survey data were collected online through Qualtrics and processed by the researcher. This study's research design consisted of a multilevel longitudinal structure. This study sought to analyze differences among the intervention groups' participants to assess changes in student achievement and to correlate those changes with students' problem-solving self-efficacy and anxiety.

The College of Engineering granted access after consent was given by the department. Collection of student survey data occurred during the semester within a week of the administering each

midterm exam. Students' problem-solving self-efficacy and anxiety was measured by the Network Theory Self-Efficacy Inventory (NTSEI) rating scale. This was an adopted and modified version of the Mathematics Self-Efficacy Questionnaire (MSEQ) developed by May [31]. Both the NTSEI and MSEQ are 29-item scales that employed ordinal response items (1= *Never* to 5= *Usually*) that measured students' problem-solving self-efficacy and anxiety [30, 32]. For scale interpretation, higher problem-solving self-efficacy scores indicated higher self-efficacy and lower anxiety scores indicated lower anxiety.

Study Results

RQ1

The first research question investigated the effects of the use of the MLE tutor on students' problem-solving self-efficacy and anxiety. More specifically, the first research question investigated if the type of intervention (CITS vs. CTT) was related to students' problem-solving self-efficacy (NTSEI) scores. A multilevel means-as-outcomes linear growth model showed a marginally significant, negative effect of the use of the CITS intervention (β_{01} = -0.48; p = .054) on NTSEI scores (where β_{01} is the effect of the CITS intervention on NTSEI scores) with a medium to large effect size. Specifically, among students who utilized the CITS intervention, their related problem-solving self-efficacy scores were lower than those students who utilized the CTT intervention. Furthermore, there were no significant effects of either intervention on students' problem solving anxiety (PSA) scores.

RQ2

The second research question investigated the relationship between students' problem-solving self-efficacy, anxiety and student achievement. More specifically, this research question sought to examine if students' exam scores, among students who utilized the CITS intervention, were related to their problem-solving self-efficacy and anxiety in comparison to those who utilized the CTT intervention. Results from a multilevel means-as-outcomes linear growth model showed a statistically significant, positive effect of student NTSEI scores ($\beta_{20} = 1.30, p < .05$) on student exam scores (where β_{20} is the effect of NTSEI scores on student exam scores) with a medium to large effect size. Specifically, among students who utilized the CITS intervention, higher problem-solving self-efficacy scores were indicative of higher exam scores.

Results from a multilevel means-as-outcomes linear growth model also showed a statistically significant, negative effect of student PSA scores ($\beta_{20} = -2.38, p < .05$) on student exam scores (where β_{20} is the effect of PSA scores on student exam scores) with a medium to large effect size. Specifically, among students who utilized the CITS intervention, as PSA scores increased, exam scores decreased. Therefore, lower problem-solving anxiety was indicative of higher exam scores.

Discussion and Conclusion

Research related to this study analyzed the relationship between MLE-based digital tutors on student achievement in an advanced Circuit Analysis (Network Theory) course. Results of multilevel modeling indicated positive significant differences between the control and treatment groups with mean student exams scores of both treatment groups higher by as much as 19% over the course of the semester.

In this part of the research study, the effects of MLE-based digital tutors on student achievement, problem-solving self-efficacy and anxiety were examined. However, for this portion of the research study, only the treatment (intervention) groups were analyzed. Examination scores and survey responses were collected from the treatment groups at three different time points during the semester. Results suggested that among students who utilized the CITS tutor, their associated problem-solving self-efficacy (PSA) was significantly lower than that of students utilizing the CTT tutor by as much as 9%. No significant relationship was found between tutor usage and problem-solving anxiety. This study's results also suggested that among students who utilized either version of the MLE intervention, their associated exam scores increased by 4% when problem-solving self-efficacy was a predictor of exams scores. That is, the higher students' problem-solving self-efficacy, the higher their exam scores. This is supported by the literature and connects current research findings with theory [33, 34]. Furthermore, this study's results suggested that among students who utilized either version of the MLE intervention, their associated exam scores decreased by 8% when anxiety was a predictor of exam scores. That is, the higher students' anxiety, the lower their exam scores. This is supported by the literature and connects current research findings with theory [35, 36].

There have been a number of research studies documenting the effect of students' affective domains in engineering disciplines [9,10,37]. More specifically, students' anxiety and self-efficacy play a large role in students' metacognitive performance and mastery of engineering fundamentals [38]. A learners' ability to think analytically when solving engineering problems is critically embedded with their ability for memory recall and cognitive-metacognitive strategies [9]. According to Hutchison [38] students' anxiety and perception of their problem-solving abilities are directly related to their academic achievement, self-confidence and program matriculation [39]. More specifically, students' problem-solving self-efficacy can directly impact their ability to function productively as an engineering student. Similarly, students with high anxiety are more likely to experience decreased academic readiness and performance [10]. Efforts to increase students' problem-solving self-efficacy and decrease anxiety have been met with varying degrees of success. However, research has suggested that tutoring systems may offer students support by increasing motivation, self-confidence and academic achievement [40-41].

This research study was paramount because it investigated a gap that was exhibited by lack of experimental research on affective domains and MLE-based digital tutors in higher education for engineering majors [38, 42, 43]. This research study was part of a much larger dissertation research study by Moses [30] which investigated over thirty (30) variables ranging from MLE-based digital tutor features to student demographics to student attributes to student affective domains to academic achievement. Further exploratory research examining students' affective domains is necessary to analyze any connections to student demographics and student attributes. For instance, Vitasari [9] suggested that gender and Yanik [10] suggested that ethnicity and engineering major

are important predictors of anxiety. Moses [30] dissertation study collected data on students' highest math course taken in college, number of engineering courses taken and student classification (freshman, sophomore, etc.) in addition to student demographics and engineering major. Analyzing these connections, if any, may be of great interest to researchers and practitioners attempting to affect positive change in engineering students' affective domains.

References

[1] Y. Tang, R. University, S. Shetty, T. S. University, X. Chen, and R. University, "Interactive Virtual Reality Games to Teaching Circuit Analysis with Metacognitive and Problem-Solving Strategies," presented at the *ASEE Annual Conference & Exposition*, Vancouver, BC, June,, 2011.

[2] H. Khalil and M. Ebner, "MOOCs Completion Rates and Possible Methods to Improve Retention - A Literature Review," *In Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications*, pp. 1236-1244, 2014.

[3] A. Belasco, "College Advice for the Career-Minded: So, you want to be an engineer?," (2015), College Transitions. [Online]. Available https://www.collegetransitions.com/blog/so-you-want-to-be-an-engineer/

[4] A. Murata and Y. Ohta, "Metacognition in Solving Process of Basic Electric Circuit Problem-Comparison of Metacognitive Characteristics between Non-major and Major Students in Electric Engineering," Computer Technology and Application, vol. 4, no. 8, pp. 415-424, Aug. 2013.

[5] T. T. Moores, J. C.-J. Chang, and D. K. Smith, "Clarifying the role of self-efficacy and metacognition as predictors of performance: construct development and test," *ACM SIGMIS Database*, vol. 37, no. 2–3, pp. 125–132, 2006.

[6] J. H. Flavell, "Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry.," *American psychologist*, vol. 34, no. 10, p. 906, 1979.

[7] J. Garofalo and F. K. Lester, "Metacognition, Cognitive Monitoring, and Mathematical Performance," *Journal for Research in Mathematics Education*, vol. 16, no. 3, p. 163, May 1985.

[8] M. M. Terras and J. Ramsay, "The five central psychological challenges facing effective mobile learning: A psychological perspective on mobile learning," *British Journal of Educational Technology*, vol. 43, no. 5, pp. 820–832, Sep. 2012.

[9] P. Vitasari, T. Herawan, M. N. A. Wahab, A. Othman, and S. K. Sinnadurai, "Exploring Mathematics Anxiety among Engineering students," *Procedia - Social and Behavioral Sciences*, vol. 8, pp. 482–489, 2010.

[10] P. Yanik, Y. Yan, S. Kaul, and C. Ferguson, "Sources of Anxiety among Engineering Students: Assessment and Mitigation," in *2016 ASEE Annual Conference & Exposition Proceedings*, New Orleans, Louisiana, 2016.

[11] B. Deken and C. Cowen, "Development of Computer Aided Learning Software for Use in Electric Circuit Analysis," in Proceedings of the 2011 IAJC-ASEE International Conference, vol. 9, pp. 507-520, 2011.

[12] T. Nwachukwu, "Circuit Tutor: Prototype of a Mobile Web-Based Intelligent Tutor in Circuit Theory." Master Thesis, Temple University, 2012.

[13] A. Mehrizi-Sani and R. Olsen, "Board # 99: An Intelligent Software Tutor for Scaffolding Solving DC-DC Converter Circuits," in 2017 ASEE Annual Conference & Exposition Proceedings, Columbus, Ohio, 2017.

[14] B. S. Rodanski, "Dynamic Web-Based Tutorial Tool," in 2006 7th International Conference on Information Technology Based Higher Education and Training, Ultimo, Australia, 2006, pp. 67–70.

[15] K. VanLehn et al., "The Andes Physics Tutoring System: Lessons Learned," International Journal of Artificial Intelligence in Education, vol. 15, no. 3, 2005.

[16] E. Kapa, "A Metacognitive Support during the Process of Problem Solving in a Computerized Environment," *Educational Studies in Mathematics*, vol. 47, no. 3, pp. 317–336, 2001.
[17] A. Wells, "Meta-Cognition and Worry: A Cognitive Model of Generalized Anxiety Disorder," Behavioral and Cognitive Psychotherapy, vol. 23, no. 03, p. 301, Jul. 1995.
[18] Bandura, A., Caprara, G. V., Fida, R., Vecchione, M., Del Bove, G., Vecchio, G. M., Barbaranelli, C., 2008. Longitudinal Analysis of the Role of Perceived Self-Efficacy for Self-Regulated Learning in Academic Continuance and Achievement. Journal of Educational Psychology, 100 (3), 525–534.
[19] M. Kargar, R. A. Tarmizi, and S. Bayat, "Relationship between Mathematical Thinking, Mathematics Anxiety and Mathematics Attitudes among University Students," Procedia - Social and Behavioral Sciences, vol. 8, pp. 537–542, 2010.
[20] L. Kvedere, "Mathematics Self-efficacy, Self-concept and Anxiety Among 9th Grade Students in Latvia," Procedia - Social and Behavioral Sciences, vol. 116, pp. 2687–2690, Feb. 2014.
[21] J. R. Anderson, A. T. Corbett, K. R. Koedinger, and R. Pelletier, "Cognitive Tutors: Lessons Learned," *The Journal of the Learning Sciences*, vol. 4, no. 2, pp. 167–207, 1995.
[22] P. H. Winne and J. C. Nesbit, "Supporting Self-Regulated Learning with Cognitive Tools," in, *Handbook of Metacognition in Education*, 1st ed. Routledge, pp. 259-277, 2009.
[23] K. Koedinger, A. Corbett, et al. *Cognitive tutors: Technology bringing learning science to the classroo*m, The Cambridge handbook of the learning sciences, pp. 61–78, 2006.
[24] V. A. Aleven, B. McLaren, I. Roll and K. R. Koedinger, "Toward tutoring help seeking," In *Proceedings of the 7th International Conference on Intelligent Tutoring System*, pp. 227-239. Berlin: Springer-Verlag, 2004.
[25] B. Butz, M. Duarte and S. Miller, "An Intelligent Tutoring System for Circuit Analysis," *IEEE Transactions on Education*, vol. 49, no. 2, pp. 216–23, 2006.
[26] S. J. Derry and S. P. LaJoie, "A middle camp for (un)intelligent instructional computing: An introduction," In *Computers as cognitive tools*, Hillsdale, NJ: Lawrence Erlbaum Associates, 1993.
[27] A. S. Gertner and K. VanLehn, Andes: a coached problem solving environment for physics. In Intelligent Tutoring Systems: 5th International Conference, ITS 2000, Montreal, Canada, 19-23 June 2000, Proceedings, pp. 133-142. Springer, Berlin, Heidelberg, 2000.
[28] A. C. Graesser, G. T. Jackson and B. McDaniel, "AutoTutor holds conversations with learners that are responsive to their cognitive and emotional states," Educational Technology, vol. 47, pp. 19-22, 2007.
[29] K. R. Koedinger and J. R. Anderson, J.R., "Reifying implicit planning in geometry: Guidelines for model-based intelligent tutoring system design," In Computers as Cognitive Tools, Hillsdale, NJ: Erlbaum, 1993.
[30] K. Moses, "Examining the Effects of Using a Mobile Digital Assistive Tutor for Circuit Analysis on Students' Academic Achievement, Problem-Solving and Self-Efficacy," PhD Thesis, Northern Illinois University, 2019.
[31] D. K. May, "Mathematics self-efficacy and anxiety questionnaire," PhD Thesis, University of Georgia, 2009.
[32] S. Glynn and D. K. May, "A Mathematics Self-Efficacy Questionnaire for College Students," University of Georgia.
[33] A. Bandura, G. V. Caprara *et al.*, "Longitudinal analysis of the role of perceived self-efficacy for self-regulated learning in academic continuance and achievement.," *Journal of Educational Psychology*, vol. 100, no. 3, pp. 525–534, 2008.
[34] A. Bandura, B. J. Zimmerman, and M. Martinez-Pons, "Self-Motivation for Academic Attainment: The Role of Self-Efficacy Beliefs and Personal Goal Setting," *Am Educ Res J*, vol. 29, no. 3, pp. 663–676, Sep. 1992.
[35] N. E. Betz, "Prevalence, distribution, and correlates of math anxiety in college students," *Journal of Counseling Psychology*, vol. 25, pp. 441-448, 1978.
[36] G. Hackett and N. E. Betz, "An Exploration of the Mathematics Self-Efficacy/Mathematics Performance Correspondence," *Journal for Research in Mathematics Education*, vol. 20, no. 3, p. 261, May 1989.

[37] S. W. McQuiggan, B. W. Mott, and J. C. Lester, "Modeling self-efficacy in intelligent tutoring systems: An inductive approach," *User Modeling and User-Adapted Interaction*, vol. 18, no. 1–2, pp. 81–123, Feb. 2008.

[38] M. A. Hutchison, D. K. Follman, M. Sumpter, and G. M. Bodner, "Factors Influencing the Self-Efficacy Beliefs of First-Year Engineering Students," *Journal of Engineering Education*, vol. 95, no. 1, pp. 39–47, Jan. 2006.

[39] E. Zakaria and N. M. Nordin, "The Effects of Mathematics Anxiety on Matriculation Students as Related to Motivation and Achievement," *Eurasia Journal of Mathematics, Science & Technology Education*, vol. 4, no. 1, pp. 27-30, 2008.

[40] S. Alexander, A. Sarrafzadeh, and S. Hill, "Easy with Eve: A Functional Affective Tutoring System," *Workshop on Motivational and Affective Issues in ITS, 8th International Conference on ITS 2006*, pp. 38-45, 2006.

[41] M. A. Ringenberg and K. VanLehn, "Scaffolding problem solving with annotated, worked-out examples to promote deep learning," in *Intelligent tutoring systems*, pp. 625–634, 2006.

[42] M. Alves, C. S. Rodrigues, A. M. A. C. Rocha, and C. Coutinho, "Self-efficacy, mathematics' anxiety and perceived importance: an empirical study with Portuguese engineering students," *European Journal of Engineering Education*, vol. 41, no. 1, pp. 105–121, Jan. 2016.

[43] Q. Brown, "Mobile intelligent tutoring system: moving intelligent tutoring systems off the desktop," PhD thesis, Drexel University, 2009.