Interdisciplinary Initiative for Infusion of Virtual Labs in IT and Engineering Degree Programs

Usha Jagannathan
Ira A. Fulton Schools of Engineering, Arizona State University, usha.jagannathan@asu.edu

Risa Blair
Information Systems Technology & School of General Education, Kaplan University, rblair@kaplan.edu

Abstract - **In recent years, online learning has taken a new dimension with the introduction of virtual labs in the higher education field. There has been a huge initiative to engage faculty to integrate virtual labs in the IT and Engineering studies. This paper explores the benefits of integrating virtual labs into computer engineering curriculum with the anticipation that this virtual hands-on experience will help engage students in connecting the abstract theory and concepts to practice. Virtual labs are in fact preferred in many higher educational online settings for addressing the inability to visualize complex phenomena in a virtual setting that will help students to attain their learning goals. As we know, faculty plays a vital role in determining the success or failure of developing the content to align with the course learning outcomes. By employing an interdisciplinary initiative, this research paper will help inspire online educators in IT and Engineering field to integrate virtual labs for their courses that would highly motivate students to apply their theoretical learning to solve real-world application problems.**

Index Terms - Adoption, Diffusion, Innovation, Integration, Simulation, Software, Virtual Laboratories, Web-based Instruction, Web-Enhanced Courses.

INTRODUCTION

Technology use in higher education degree programs today has become a requisite in terms of social grounds and a greater motivator for faculty to intellectually stimulate students and help them succeed in their academic goals (Ke, 2010; Korkmaz, 2013). In order for students to learn 21st century skills, faculty members have to teach them differently than how it was done in the past. Diffusion of innovation in an academic setting can change the habits of technology use in individual faculty but can take as long as five to ten years (Kershaw, 1996). The rate at which technology is adopted at present in higher educational institutions varies considerably and applying Rogers' (2003) diffusion of technological innovation model to academia suggests that a significant proportion of faculty react slowly in embracing technological innovation (Hall & Jr., 2013). There are a substantial number of faculty members who do not use or furthermore are reluctant to adopt technology today, and that can many times lead to a less effective learning experience for the students (Akroyd, Patton & Bracken, 2013; Lin, Singer & Ha, 2010) mainly in science and engineering disciplines. Therefore, effective use of technology in the classrooms will require a paradigm shift from being a teaching franchise to being an enterprise that emphasizes learning (Rogers, 2000).

Most faculty actually may want to promote web-based instruction, instead feel they are inadequately prepared to adopt technology in their classrooms (Sang, Valcke, van Braak & Tondeur, 2010) or resist change to integrate technology into learning (Agyei & Voogt, 2011) especially in Information Technology (IT) degree coursework (McDonald et al., 2013). With the increasing demand for education and training in this cutting digital age, virtual labs will play a critical role in our IT curriculum and teaching as online education becomes indispensable.

It is very well-documented in research that faculty integrating virtual labs in web-based environment in higher education online degree programs for the design of appropriate learning tasks for IT programs, does yield successful learning outcomes through increased access to course materials and in collaborating with their peers in constructing new knowledge (Lee & Tsai, 2010; McDonald et al., 2013; Worley, 2011; Raman, Achuthan & Nedungadi, 2013; Wu, Fulmer & Johnson, 2014). Many IT courses in college and university settings have adopted virtual environments for the hands-on lab portion especially for online and web-enhanced classrooms as they were able to accommodate more students and proved less expensive to operate (Rutten et al., 2012). Rutten also stated that using simulation leads to more motivated students and improved teaching and learning in the online classrooms (2012). In succession, this has also been suggested that adopting virtual labs by faculty in the IT classrooms provide insight into the degree of student achievement and the effectiveness of instructional methods on learning content (Yuan, Schlough & Anderson, 2013) by reinforcing higher order technology skills for students with an enriching learning experience (Jagannathan & Blair, 2013; Son, Irrechukwu & Fitzgibbons, 2014). The infusion of virtual laboratories is still in its infancy in Information Technology (IT) degree courses and through interdisciplinary initiative across other engineering disciplines, will enhance the learning experience through virtual labs in connecting the abstract theory and concepts to practice (Wu et al., 2014). The practical obstacles may be less important than empowering instructors

to adopt virtual labs for their IT classrooms, as the impact of web-based instruction is largely a function of a faculty's perspective and ability (Beaudoin, 2013; Hung & Jeng, 2013).

LITERATURE REVIEW

Review of literature indicates that faculty integrating technology in higher education classrooms provide students with an instructional, independent, self-directed and student-centered learning opportunity in ways that are both acceptable and highly beneficial to them (Marrocco, Kazer & Neal-Boylan, 2014). Colleges and universities recently are more focused on the empowerment of their faculty members than ever before, in trying to train them to redesign their teaching strategies to be interwoven into pedagogical content (Barnes & Solomon, 2014). The process of training the faculty staff with new awareness of the role that technology can play in socio-constructivist pedagogy also recognizes the key role the faculty has to play in introducing change in their academic institutions (Mayes, Morrison & Mellar, 2009).

Adopting technology in web-based instruction is therefore the need of the hour for faculty to use in teaching the college-level courses, as it can largely assists the students to develop the 21st century skills such as, critical thinking and problem solving (Dede, 2010), creativity and innovation, effective communication and interpersonal skills, collaboration with their peers (Saavedra & Opfer, 2012), knowledge sharing (Worley, 2011), leadership skills; thereby sufficiently furnishing the students to meet the challenging demands in an era of global technology advancement (Singh, 2012). Especially in information technology and a variety of other engineering disciplines, courses taught by the faculty using web-based instruction greatly enabled students to respond more positively to class lesson activities when supplemented with technology (McLoughlin & Lee, 2010; Paily, 2013).

If higher educational institutions fall short to offer quality based web-enhanced instruction, then there would be a considerable amount of risk in losing potential students to other institutions that adopt more innovative approaches to education (Hoffmann & Dudjak, 2012). Hence, faculty members who are likely to teach web-enhanced or online courses ought to be familiar with web-based teaching methods to infuse virtual labs in their course activities for their pedagogical practices (Hall Jr., 2013; Oncu & Cakir, 2011; Wu et al., 2014).

VIRTUAL HANDS-ON IT LABS

Virtual labs are recent multimedia technology innovation that is being incorporated in online degree courses to perform simulated labs (Wu et al., 2014). Virtual laboratories are simulation-based interactive labs used to interactively design and conduct controlled experiments (Amorim et al., 2014). Many courses in colleges and universities have adopted a significant portion of virtual lab component into the coursework that would provide authentic learning and also help them to apply the theory learned into the hands-on virtual IT labs (De Jong, Linn & Zacharia, 2013).

In several ways, virtual labs have been augmenting the hands-on physical IT lab settings by allowing students to learn most part of the actual lab prior to physically seeing or experimenting with the real equipment. The functionality of virtual labs is often improved with online lectures and step-by-step instructions to work on the lab tasks (Gomes and Bogosyan, 2009). Simulation integrated learning has become vital to IT and computer engineering disciplines and it is particularly relevant to the integration of new system design concepts and technologies for introductory courses in the IT degree programs (Ertmer et al., 2012; Lee, Blackwell, Drake & Moran, 2014).

Traditionally, IT and computer engineering curricula about networks, information security, IT certification courses use textbook or e-book instruction and hands-on lessons, which are effective approaches for teaching students terms and definitions, the procedural use of network addresses and protocols, and how to build network and enforce security to protect data (De Jong et al., 2013). However, students often lack conceptual understanding in their subject matter. A course in computer networking essentials needs to be supported by a dedicated laboratory that have to equipped with all the basic networking components: servers, workstations, cables, connectors, routers, switches, bridges, etc. An important element of a laboratory's infrastructure is a variety of network configurations for specific experiments and interesting and cost-effective alternative is the concept of virtual labs (Dobrilovic, Jevtic & Odadzic, 2013). Virtual labs are an ideal solution in distance education, as well as for universities and colleges with limited financial recourses (Karakasidis, 2013).

Virtual labs offer efficiencies over physical labs because they typically require very little time in logging into the lab site electronically and provide results of lengthy investigations instantaneously (Kratzke, 2012; De Jong et al., 2013). Previous research have shown that the value of technology-enhanced materials guide learners to use dynamic, interactive visualizations of science phenomena and has proven greater student learning gains (Gerard et al., 2013). The power of these interactive simulation labs to improve student understanding depends on the teacher involvement in the course design in science, IT and engineering curriculum (Raman et al., 2013). Both physical and virtual lab experiments can succeed when they include consistent weekly assignment tasks and face-to-face versus online instructor guidance to help students distinguish among their own ideas and the ones demonstrated through the lab tasks (De Jong et al., 2013).

For virtual lab experiments, today's technology allow to log the student attempts and use the information to diagnose random or uninformative investigations to prompt students to revise their experimentation strategies for instance with the computer networking course and to reflect on their findings (Kollöffel & Jong, 2013). Instructors can review the

logs of the students' work to flag ideas for class discussions either face-to-face or through online discussion forums, plan their lessons, identify groups of students who need specialized tutoring, and refine their instruction (Chiu & Linn, 2011).

Kollöffel & de Jong (2013) study emphasized on how to facilitate the acquisition of conceptual understanding of electric circuits through virtual labs for students in secondary vocational engineering education. Through quasi-experimentation, the study discovered that students using the virtual labs scored significantly higher than the traditional labs on conceptual understanding, procedural skills and in solving complex problems. The study recommends that teachers should supplement with inquiry learning within virtual labs for their traditional classes and through the support of instructor guidance, the virtual labs can be made effective.

ASSESSING THE TRADITIONAL AND VIRTUAL LABORATORY

In a traditional environment, programming or networking design can be learned hands-on with the help of instructor guidance and using physical equipment. However, the fundamental limitation with hands-on traditional labs is that the student visits the campus only twice a week, making it difficult for the average student to relate the theory into practice. When using virtual labs, educational institutions can target effective learning along with eliminating expensive infrastructure, reducing costs, centralizing IT infrastructure into one data repository that would virtually provide access or using third-party vendor software into the course curriculum for integrating virtual labs into the course content. Also, students and faculty can learn and use the virtual lab component whenever they can to fit their schedule.

In order to find out the performance measure of the undergraduate students using traditional and virtual labs, comparative study was done looking at students' class grade average for a 3-credit course, where the in-class lab assignments were done using Physical lab and the homework lab assignments were done using virtual labs.

To do a fair judgment between the two kinds of laboratories, the assessment was conducted on courses using both physical and virtual labs during the semester period that runs for 16 weeks for 4 different courses across IT and networking discipline in BS degree program in engineering education.

Students in introductory computer engineering or IT course use MyITLab (Pearson Higher Education, 2015) simulation tool to learn the Office applications thoroughly. For learning networking skills using virtual labs, labsim (TestOut Corporation, 2015) software was used and for database labs, toolwire (ToolWire Inc., 2015) software was integrated into the coursework.

Figure 1 is a screenshot of a labsim simulation. The simulation snapshot shown in Figure 1 guides the user to setup a home office network. The lab task assigned in the Figure 1 is to have the student connect the components to setup the internet connection for a home network.

Figure 2 is a screenshot of toolwire simulation. The snapshot shown in Figure 2 instructs the user to connect to the database remote server and create queries to retrieve data from the already existing tables.

MyITLab (Pearson, 2015) offers simulation environment for Microsoft Office applications for students to learn and reinforce on difficult concepts tied to the course material.

TestOut LabSim (TestOut, 2015) offers interactive tools in delivery of technical courses such as networking, CISCO certification and networking security online.

Toolwire (Toolwire, 2015) delivers hands-on virtual desktop technology training solutions for online and blended learning courses by providing live access to real technology.

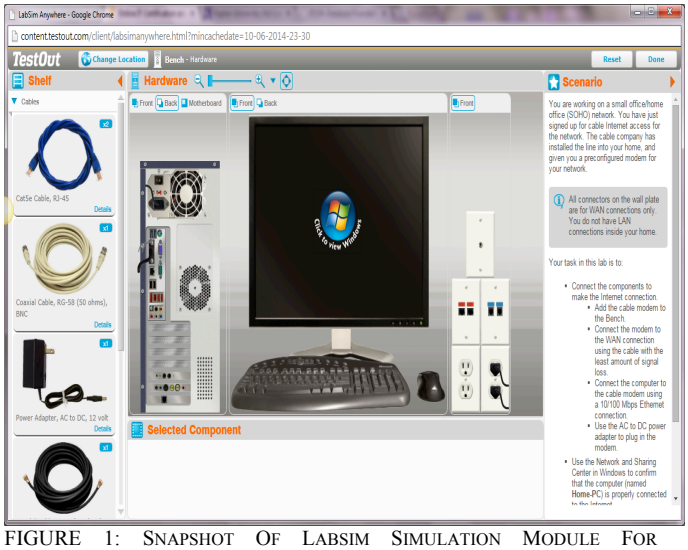

FIGURE 1: SNAPSHOT OF LABSIM SIMULATION MODULE FOR NETWORKING VIRTUAL LAB

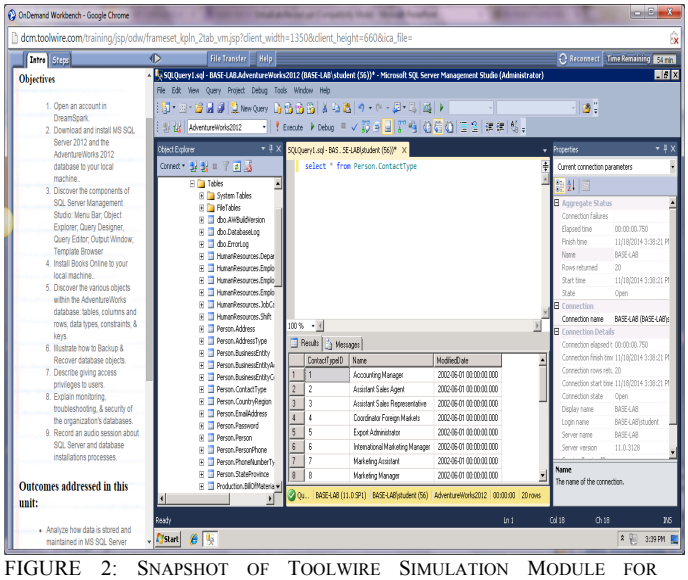

FIGURE 2: SNAPSHOT OF TOOLWIRE SIMULATION MODULE FOR DATABASE PROGRAMMING VIRTUAL LAB

Table 1. Data Analysis of Student Grade Percentage of Spring and Fall 2014 courses

Number of Undergraduate Students (BS - IT & Computer Information Systems)	Year Enrolled To Expected Graduation Date	Courses Taken by BS Students using Traditional & Virtual Labs	Course Performance Measured with Traditional Lab (In-Class Lab Assignments)	Course Performance Measured with Virtual Lab (Homework Lab Assignments)
34	2011-2015	Introduction to Software Applications (Using Microsoft Office software & for Virtual Lab using MyITLAB simulation)	81%	82%
30	2012-2016	Networking Essentials (Physical Hands-on Lab & for Virtual Lab using LabSim)	74%	82%
26	2012-2016	Principles of Database Management (Installed SQL Server database software & for Virtual Lab using ToolWire)	73%	86%
29	2011-2015	Oracle Database Design (Installed Oracle Database software and for remote lab using University server connect)	75%	84%

TABLE 1: SURVEY DONE AT A MIDWESTERN UNIVERSITY OF STUDENTS ENROLLED IN BS IT AND COMPUTER INFORMATION SYSTEMS PROGRAM (UNIVERSITY INSTITUTIONAL RESEARCH & FACULTY PROVIDED DATA TAKEN FOR SELECTIVE COURSES HELD IN SPRING & FALL 2014)

ASSESSMENT RESULTS

The comparative analysis shows that lab activities completed through a virtual lab have led the students to acquire enhanced learning outcomes and in turn yielded better academic performances overall compared to traditional labs. Courses assessed were 'Introduction to Software Applications' and 'Oracle Database Design' that were taught in Spring 2014 at a Midwestern University and 'Networking Essentials' and 'Principles of Database Management' taught in Fall 2014. All these four courses were enabled with both hands-on and virtual labs to complete the course assignments. The course performance was measured from collecting the data from the University's Institutional Research department for the courses taught by the respective faculty in assessing the in-class and homework lab activities.

Analysis revealed how the simulation tool when used along with the traditional lab activities improved students' overall learning outcomes. However, this study did not discuss about how the instructors infused the virtual labs in their curriculum or what pedagogical methods were followed in adopting virtual labs to achieve their intended learning outcomes. Virtual labs are in fact preferred in many higher educational online settings for addressing the inability to visualize complex phenomena in a virtual setting that will help students to attain their learning goals through virtual labs. Thus, when used simulation labs for the students by adopting this technology innovation for connecting the abstract theory and concepts to practice, can promote enriched learning and increase student success across all levels of IT and Computer Engineering disciplines as necessary.

Graduates joining IT industry as technicians, programmers and network engineers often have limited practical knowledge, but repeated experimentation using virtual lab modules would help consolidate their hands-on experience and enhance creative skills needed to tackle more complicated problems such as troubleshooting a network or administering a corporate database from the scenarios shared in this paper with the aid of simulation labs. Also, to prepare for the workforce development, colleges and universities should be engaged to promote the development of virtual e-learning modules across all engineering disciplines in encouraging faculty to integrate virtual labs into their course content as necessary that are relevant to the specific needs of the industry.

Higher Education institutions should recognize the constant changing and learning needs of students, and the benefits of creating engaging course content modules in engineering education for online and on-campus degree programs. Virtual lab is an integral part of the students' learning process in creating better engineers and professionals of tomorrow (Agarwal, Uppaluri & Verma, 2013). Moreover, the simulated environment provides students the freedom to make mistakes and in the process learn from them as many times as they would like to for reinforcing the concepts learned (Zhang & Li, 2014). Through the interdisciplinary initiative in integrating the virtual laboratory across engineering curriculum, students can have authentic learning experiences to apply it in the real world. It is no doubt in this digital age, virtual labs are a boon to the student and professional community, to learn from anywhere-anytime by reinforcing the concepts in enabling them to prepare for the real world applications and systems.

CONCLUSION

Virtual and traditional labs may have its own advantages and disadvantages, however blending the two lab environment together may result in optimal learning experience as seen through this study. Virtual labs have been reported to enhance conceptual understanding, and this study shows clearly that conceptual understanding have risen with the academic performance of the students in complimenting virtual lab with hands-on lab for the four different courses the students took in the last Spring and Fall 2014 at a Midwestern University. However, the study did not perform a qualitative study and when addressed that, the faculty perceptions on adopting virtual labs across program disciplines and continue to integrate into their curriculum could be learned better.

REFERENCES

[1] Agarwal, A., Uppaluri, R., & Verma, A. (2013). LabVIEW based e-learning portal for virtual mass transfer operations laboratory. *CSI Transactions on ICT*,*1*(1), 75-90.

[2] Agyei, D. D., & Voogt, J. M. (2011). Exploring the potential of the will, skill, tool model In Ghana: predicting prospective and practicing teachers' use of technology. *Computers & Education, 56*(1), 91–100.

[3] Akroyd, D., Patton, B., & Bracken, S. (2013). Factors that predict full-time community college faculty engagement in online instruction. *Community College Journal of Research and Practice*, *37*(3), 185-195.

[4] Amorim, T., Tapparo, L., Marranghello, N., Silva, A. C., & Pereira, A. S. (2014). A Multiple Intelligences Theory-based 3D Virtual Lab Environment for Digital Systems Teaching. *Procedia Computer Science, 29*(1), 1413-1422.

[5] Barnes, Y., & Solomon, Y. (2014). Empowering teachers as learners: Continuing professional learning programmes as sites for critical development in pedagogical practice. In *Workplace Learning in Teacher Education* (pp. 137-150). Springer Netherlands.

[6] Beaudoin, M. (2013). The Evolving Role of the Instructor in the Digital Age. *Learning Management Systems and Instructional Design: Metrics, Standards, and Applications*, 233-262.

[7] Chiu, J. L., & Linn, M. C. (2011). Knowledge integration and WISE engineering. *Journal of Pre-College Engineering Education Research (J-PEER), 1*(1), 2.

[8] Dede, C. (2010). Comparing frameworks for 21st century skills. *21st century skills: Rethinking how students learn*, 51-76.

[9] De Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science, 340*(6130), 305-308.

[10] Dobrilovic, D., Jevtic, V., & Odadzic, B. (2013). Expanding Usability of Virtual Network Laboratory in IT Engineering Education. *International Journal Of Online Engineering, 9*(1), 26.

[11] Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*(2), 423-435.

[12] Gerard, L., Liu, O. L., Corliss, S., Varma, K., Spitulnik, M., & Linn, M. C. (2013). Professional Development Programs for Teaching with Visualizations. *In Emerging Technologies for the Classroom* (pp. 63-78). Springer New York.

[13] Gomes, L., & Bogosyan, S. (2009). Current trends in remote laboratories. *Industrial Electronics, IEEE Transactions on*, *56*(12), 4744-4756.

[14] Hall Jr., O. P. (2013). Assessing faculty attitudes toward technological change in graduate management education. *Journal of Online Learning & Teaching*, *9*(1).

[15] Hoffmann, R. L., & Dudjak, L. A. (2012). From onsite to online: Lessons learned from faculty pioneers. *Journal of Professional Nursing*, *28*(4), 255-258.

[16] Hung, W. C., & Jeng, I. (2013). Factors influencing future educational technologists' intentions to participate in online teaching. *British Journal of Educational Technology*, *44*(2), 255-272.

[17] Jagannathan, U., & Blair, R. (2013). Engage the Disengaged. *Distance Learning, 10*(4), 1-7.

[18] Karakasidis, T. (2013, March). Virtual and remote labs in higher education distance learning of physical and engineering sciences. *In Global Engineering Education Conference (EDUCON), 2013 IEEE* (pp. 798-807). IEEE.

[19] Ke, F. (2010). Examining online teaching, cognitive, and social presence for adult students. *Computers & Education, 55*(1), 808-820.

[20] Kershaw, A. (1996). People, planning, and process: The acceptance of technological innovation in post-secondary organizations. *Educational Technology, 36*(5): 44-48.

[21] Kollöffel, B., & Jong, T. (2013). Conceptual understanding of electrical circuits in secondary vocational engineering education: Combining traditional instruction with inquiry learning in a virtual lab. *Journal of Engineering Education, 102*(3), 375-393.

[22] Korkmaz, O. (2013). The effects of different interaction types in web-based teaching on the attitudes of learners towards web based teaching and internet. *Turkish Online Journal of Distance Education (TOJDE), 14*(2), 208-224.

[23] Kratzke, N. (2012). Virtual Labs in Higher Education of Computer Science Why they are Valuable? How to Realize? How much will It Cost?. *Education, 2*(7), 239-246.

[24] Lee, J., Blackwell, S., Drake, J., & Moran, K. (2014). Taking a Leap of Faith: Redefining Teaching and Learning in Higher Education Through Project- Based Learning. *Interdisciplinary Journal Of Problem-Based Learning, 8*(2), 1-17.

[25] Lee, M. H., & Tsai, C. C. (2010). Exploring teachers' perceived self efficacy and technological pedagogical content knowledge with respect to educational use of the World Wide Web. *Instructional Science*, *38*(1), 1-21.

[26] Lin, C., Singer, R., & Ha, L. (2010). Why university members use and resist technology? A structure enactment perspective. *Journal of Computing in Higher education*, *22*(1), 38-59.

[27] Marrocco, G. F., Kazer, M. W., & Neal-Boylan, L. (2014). Transformational Learning in Graduate Nurse Education Through Podcasting. *Nursing Education Perspectives*, *35*(1), 49-53.

[28] Mayes, T., Morrison, D., & Mellar, H. (2009). Transforming higher education through Technology-enhanced learning. *Higher Education.* Retrieved from http://www.heacademy.ac.uk/assets/documents/learningandtech/transforming.pdf

[29] McDonald, J., Wright, S., Kilcoyne, M. S., Champion, S., & Fountain, E. (2013). Millennials: Technologies and expectations. *Association of Business Information Systems*, 69-72. Retrieved from http://www.abis-fbd.org/

[30] McLoughlin, C., & Lee, M. J. W. (2010). Personalised and self regulated learning in the web 2.0 era: International exemplars of innovative pedagogy using social software. *Australasian Journal of Educational Technology, 26*(1), 28-43.

[31] Oncu, S., & Cakir, H. (2011). Research in online learning environments: Priorities and methodologies. *Computers & Education*, *57*(1), 1098-1108.

[32] Paily, M. U. (2013). Creating constructivist learning environment: Role of "web 2.0" technology. *International Forum of Teaching and Studies, 9*(1), 39-50. Retrieved fromhttp://www.americanscholarspress.com/

[33] Pearson Higher Education (2015). Pearson's MyITLab: Where your course comes alive. Retrieved from http://www.pearsonmylabandmastering.com/northamerica/myitlab/

[34] Rogers, D. L. (2000). A paradigm shift: Technology integration for higher education in the new millennium. *Educational Technology Review,* 13, 19-27, 33.

[35] Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education*,*58*(1), 136-153.

[36] Saavedra, A. R., & Opfer, V. D. (2012). Learning 21st-century skills requires 21st-century teaching. *Phi Delta Kappan*, *94*(2), 8-13.

[37] Sang, G., Valcke, M., van Braak, J., & Tondeur, J. (2010). Student teachers' thinking processes and ICT integration: predictors of prospective teaching behaviors with educational technology. *Computers & Education, 54*(1), 103–112.

[38] Singh, N. (2012). Integrating technology in 21st century classrooms: Path towards envisioning the future. *TechnoLearn: An International Journal of Educational Technology*, *2*(1), 19-28.

[39] Son, J., Irrechukwu, C., & Fitzgibbons, P. (2014). Virtual Lab for Online Cyber Security Education. *Communications of the IIMA*, *12*(4), 5.

[40] TestOut. (2014). *LabSim Educational Solutions.* Retrieved from http://www.testout.com/home/educator-resources/labsim-educational-solutions

[41] Toolwire. (2015). *Toolwire OnDemand Workbench.* Retrieved from http://www.toolwire.com/

[42] Yuan, D., Schlough, S., & Anderson, B. (2013). Using outcome based learning assessment to evaluate and improve the hands-on networking course. *Journal of Computing Sciences in Colleges*, *29*(2), 220-228.

[43] Worley, K. (2011). Educating college students of the Net generation. *Adult Learning*, *22*(3), 31-39. Retrieved from http://ctlt.waubonsee.edu/files/pdfs/Orientations/2013%20Spring/teaching%20the%20Gen-Y%20student.pdf

[44] Wu, D., Fulmer, J., & Johnson, S. (2014). Teaching Information Security with Virtual Laboratories. In *Innovative Practices in Teaching Information Sciences and Technology* (pp. 179-192). Springer International Publishing.

[45] Zacharia, Z. C., & de Jong, T. (2014). The Effects on Students' Conceptual Understanding of Electric Circuits of Introducing Virtual manipulatives within a Physical Manipulatives-Oriented Curriculum. *Cognition and Instruction, 32*(2), 101-158.

[46] Zhang, D., & Li, Y. (2014, January). Improving Student Learning in Computer Science Courses by Using Virtual OpenCL Laboratory. In *2014 International Conference on Management, Education and Social Science (ICMESS 2014)*. Atlantis Press.

AUTHOR INFORMATION

Usha Jagannathan, Lecturer & Capstone Chair, Department of Information Technology, Ira A. Fulton Schools of Engineering, Arizona State University, AZ.

Risa Blair, Adjunct Professor & Training Consultant, Department of Information Systems Technology & School of General Education, Kaplan University, Iowa.