Student Perceptions of a Hands-on Delivery Model for Asynchronous Online Courses in Information Security

Abdullah Konak, Jungwoo Ryoo, and Sadan Kulturel-Konak

***Abstract*—In this paper, we introduce a delivery model for asynchronous online courses in information security. We investigate whether it is possible to provide distance learning students with rigorous and comprehensive learning in a subject area which demands hands-on experimentation like information security. The presented delivery model depends on effective uses of virtual computing technologies, content richness, and collaborative learning strategies. The preliminary findings from two asynchronous, online information security courses support the benefits of the delivery model; however, we have also identified significant problems with the overall effectiveness of team collaboration in the completion of hands-on activities.**

***Index Terms*—Distance learning, virtual computer laboratories, hands-on learning, collaborative learning.**

I. Introduction

THE acceleration of change in the landscape of higher education has increased hand-in-hand with the advances in information technology and the Internet. The most noticeable change is the rapid growth of distance learning, and accordingly, many higher education institutions have developed the capacity to deliver distance learning. A Babson College research report [1] contends that 6.7 million students took at least one online course in Fall 2011, representing 32% of the total enrollment in degree-granting postsecondary institutions. It is estimated that the market for self-paced e-learning products and services will grow to 49.6 billion in 2014 [2].

Distance learning promises a great opportunity to broaden the reach of STEM education, by presenting it to a larger population of students. However, distance learning has also been criticized for lacking in certain areas such as teamwork, and hands-on learning, both of which are vital to engineering and information technology education. In this paper, we present a distance learning delivery model emphasizing hands-on learning using virtual computing. We discuss how student learning can be enhanced in asynchronous, online information security courses through the use of hands-on and collaborative learning strategies in a virtual computer laboratory. The presented online delivery model is based on the High Fidelity E-Learning Model [3], which was developed by the Software Engineering Institute at Carnegie Mellon. We further enhanced this model by including two additional layers as discussed in the following sections. In the past two years, we designed and offered two online information security courses (a network security course and an e-commerce security course) and collected data to answer the following research questions:

1) Can an asynchronous online course provide distance-learning students with rigorous and comprehensive hands-on learning experiences in a virtual computer laboratory (VCL)?
2) Which aspect of the online delivery model does have the most positive impact on student learning experience?
3) In asynchronous hands-on distance learning, if collaborative learning strategies are implemented in a VCL, can student learning be enhanced well beyond enriching content delivery?

In this paper, we introduce our preliminary findings based on two network security classes.

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II. Virtual Computer Laboratories and Description of the CVCLAB

Virtualization is an approach for decoupling the underlying physical resources of a computer from the operating systems, applications, and users. The concept of virtualization is very broad, and the scope of its application to various information technologies ranges from servers and their operating systems to applications, networks, and even devices such as mobile phones. In a traditional server environment, a physical server hosts one instance of an operating system while supporting multiple applications. With virtualization, the server, storage, and network become logical representations of these items. These resources are controlled through software and can be shared between multiple virtual computers which are software emulations of actual operating systems. In a virtualized environment, a single physical computer, called host, may be running many virtual computers with different operating systems, network connections, storage devices, and applications.

In the last decade, advances in virtualization led to a rise in the use of Virtual Computer Laboratories (VCLs) as a new means of providing students with hands-on experimentation in the information technology area, especially in the growing field of information security. VCLs are being used to enhance student learning in various ways. In fields such as information security, where hands-on experimentation with different computer operating systems is extremely important, VCLs are used to give students the skills necessary in the corporate world where a broad range of information technologies exist. In engineering fields, VCLs provide students with remote access to specialty software packages which are frequently used in such classes. In asynchronous distance learning, VCLs enable students to perform self-paced hands-on activities remotely. Overall, VCLs have reduced the cost of establishing and maintaining specialized computer laboratories, made campus computing resources available to students at anywhere and anytime, and provided flexible and secure computing environments for many institutions.

We have implemented a virtual computing environment entitled the Collaborative Virtual Computer Laboratory (CVCLAB) in order to provide students with an environment in which they can experiment with complex and high risk information technology skills without any concern. Supporting collaborative learning was one of the primary objectives in the design of the CVCLAB. The first technical requirement to achieve this objective is to ensure that virtual computers are interconnected. Setting up virtual computer access permissions as team-based also facilitates interaction among team members. In the CVCLAB, students are allowed to view and control their teammates' virtual computers remotely. This strategy promotes peer-to-peer distance learning by encouraging skilled students to help remotely their teammates who are not as skilled as themselves.

These technical requirements are relativity straightforward to implement. In addition to the technical aspects of the CVCLAB, the design of hands-on activities is important to promote collaborative learning. In our earlier research, we have shown that if in-class hands-on activities in the CVCLAB are designed based on an inquiry-based framework rather than a cookbook approach, students can achieve a higher level of learning [4], [5]. We have also observed that student-to-student interactions in the CVCLAB have a significant positive impact on the competency development of students [6].

III. Description of the Online Delivery Model

Based on Gardner's theory of multiple intelligence [7], [8], e-learning research suggests that asynchronous, technology-based content delivery should use multiple channels (text, audio, video, and interactive learning objects) to enhance student learning. Many web-based IT training systems apply this principle using rich content delivery approaches based on multiple stimuli. The CVCLAB adds one more dimension to content richness by providing learners with an environment in which they can master subject matters through hands-on learning. Fig. 1 illustrates the delivery model used in our online information security courses. The online delivery model uses content richness to gradually build up students' skills and abilities in the network security domain through demonstrations and step-by-step activities. As students acquire more expertise, the course smoothly proceeds to a more experiential and lean-forward mode where students are expected to complete unstructured hands-on activities. In the following, we explain the details of the online delivery model.

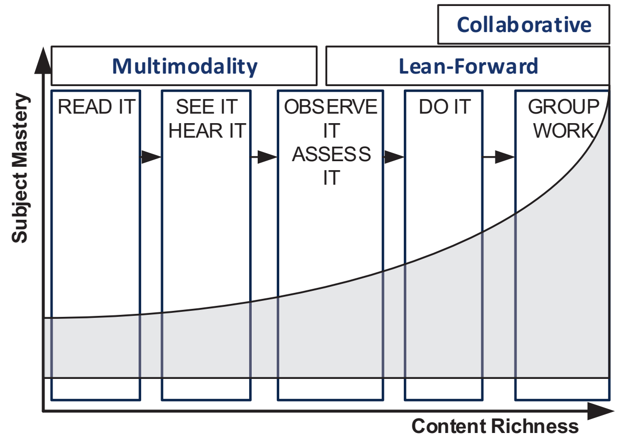

Fig. 1. Components of the course delivery model

A. READ-IT

All course content is available through a website. The course content is organized into modules, each of which includes several sections without any subsections. Our experiences have shown that students have difficulty navigating the course website if the content is organized in more than two hierarchical levels. Therefore, we selected a flat structure with only one level. Each section introduces a specific topic on a single web page which brings all related learning materials together including any reading material about the subject matter. Although the course content is very technical, the reading material is concise with minimal technical jargon presented. The objective is to introduce background on the subject matter and prepare students for the much more detailed and technical knowledge that will be presented in hands-on activities. Consequently, more detailed reading materials are typically included with hands-on activities.

B. SEE-IT

We have developed many narrated animations further to explain difficult concepts introduced in the section text. In particular, narrated animations are utilized to present procedural knowledge. We used the following strategies in creating narrated animations and incorporating them into the course content:

- Animations were created as a single page without any scene transition, wherever possible.
- They typically run a maximum of four minutes.
- They were accompanied with the written text of the animation narrative.
- The final stages of narrated animations were included in the course web page as still images. The still images of narrated animations enable students to review the concepts presented in an animation without the need to run it repeatedly.

C. OBSERVE-IT

This component of the delivery model involves short, three to five minute video clips that demonstrate essential technical skills for applying the theoretical concepts presented in a section into practice. The objective of these short video clips is to better prepare students for hands-on activities. For example, students are provided with a video clip about how to use a Network Protocol Analyzer before they are expected to capture the HTTP traffic between two computers and discover a secret password in a hands-on activity. Although hands-on activities include step-by-step instructions, students are usually unfamiliar with the enterprise-level systems used in many hands-on activities. Illustrating portions of hands-on activities in short video clips minimizes possible problems due to students' unfamiliarity with these technologies.

D. DO-IT

The DO-IT component is probably the most distinguishing aspect of the delivery model. In each course section, the subject matter is supported by hands-on activities that students are expected to complete in the CVCLAB. In the beginning of the semester, each student is assigned to a set of virtual computers, including two Linux, a Windows 7, and a Windows 2008 Server, which are dedicated to the exclusive use of the students throughout the semester. Students can remotely access their virtual computers from anywhere and at anytime without any restrictions to perform the hands-on activities.

Our empirical studies in traditional class laboratories have suggested that students can complete a lengthy hands-on activity by following step-by-step instructions, but this may not be translated into a higher mastery of the subject matter [5]. Therefore, over the years, we have modified the structure of hands-on activities from a prescriptive, cookbook approach, to a constructivist, inquiry-based method. Hands-on activities not only include instructions about the steps that students are expected to perform, but also present more detailed information about the subject matter itself and include reflection, abstract conceptualization, and active experimentation components. Typically, a hands-on activity is divided into smaller sections and include reflective activities for each section. In reflective activities, students are expected to explain or discuss why they have to perform certain steps in the activity. In abstract conceptualization components, students are expected to create a theoretical model and a generalization of what is performed in the hands-on activity. In active experimentation components, students are assigned a new task, albeit similar to what is performed in the steps without providing step-by-step instructions.

E. GROUP-WORK

These are hands-on activities that provide students with the opportunity to use the knowledge being acquired to solve problems. The successful completion of a team-lab requires virtual collaboration between two or more students, and although guidance is provided in terms of learning objectives, expected outcomes, and general step-by-step instructions, students are forced to make decisions about strategies that they apply. Team-lab activities can be lengthy and challenging, but very rewarding. Our motivation is that distance learning should also provide students with such experiential learning experiences, and VCLs such as the CVCLAB are the ideal environment for collaborative hands-on learning so long as correct instructional strategies and interventions are implemented.

F. INTERVENTIONS

E-learning research suggests that students perform better if they have access to synchronous help. With these thoughts in mind, and as the first intervention, the course instructor held regular virtual office hours. The virtual office hours have been popular particularly for hands-on activities. The CVCLAB architecture allows instructors to take control of student computers to help them remotely and to demonstrate steps if students have difficulty.

The second intervention was to use a social networking site where students could discuss technical problems, exchange tips about specific assignments, discuss review questions, and ask for help with the various technologies used in the class. All class communication took place in the social networking site. Students were instructed to post class related questions to the social networking site instead of e-mailing the course instructor. Thereby, all students would be able to see instructors' responses. In addition, problems and technical questions posted by students, particulary ones related to hands-on activities, were frequently answered by other students.

IV. Student Perceptions of the Delivery Model

In this section, we summarize the feedback of students (N=33) enrolled in an online Network Security course in 2012 and 2013. This course provides students with a comprehensive understanding of the fundamental issues and concepts of network security, the mainstream network security technologies, and those protocols that are widely used in the real world. Each student was assigned to a dedicated set of five virtual computers in the CVCLAB and completed about 40 hands-on activities, including several team labs. At the end of the semester, students were asked to evaluate the course using a questionnaire. The first section of the questionnaire included, seven-point Likert scale questions, ranging from "Strongly Agree" (1) to "Strongly Disagree" (7), as a means to measure overall student satisfaction about the CVCLAB, the course model (research question 1), and their team-lab experience during the semester in particular (research question 3). The second part had three questions to understand students' perceptions about various components of the delivery model (research question 2). In these questions, students were asked to evaluate the extent to which various components of the delivery model contributed to their learning.

Table I summarizes the student responses to the questions related to team labs and the overall satisfaction with the delivery model. Contrary to previous face-to-face activities [6], we found that students were dissatisfied with the team activities. In formative class evaluations and online focus groups, students identified scheduling common time to work on team activities as a major drawback (it should be also noted that some students were from different time zones). Because students depend on one another in order to complete team activities, they must be on the same page with their partners all the times during an activity. Thus communication problems, in terms of coordinating activity steps, emerged as another significant problem. To improve team communication, we allowed team members to control one another's virtual computers. While this strategy improved the team communication, it did not solve the problem completely.

TABLE I
STUDENT EVALUATIONS OF TEAM ACTIVITIES AND THE OVERALL COURSE MODEL (SA=STRONGLY AGREE, MA= MODERATELY AGREE, A=AGREE, N=NEUTRAL, D=DISAGREE, MD=MODERATELY DISAGREE SD=STRONGLY DISAGREE)

	Distribution of Responses (%)						
Questions	SA	MA	A	N	D	MD	SD
The course should include more team activities?	9	9	24	33	6	9	9
Team activities were more engaging.	12	12	18	39	9	3	6
I learned better in team-lab activities.	6	9	15	33	21	6	9
I am willing to take online courses like this one.	56	19	13	6	0	6	0
The course provided as much hands-on learning as a traditional course.	56	13	19	3	3	3	3

Table II presents the correlations among the survey questions about students' perceptions of the CVCLAB, hands-on activities, and difficulty of hands-on activities. In the table, the latent variable (A) Team-lab support was calculated by averaging the three survey questions related to team labs in Table I (Cronbach's Alpha=0.906). The longer versions of the other survey questions are as follows: (B) Overall, are you satisfied with the virtual computer lab (CVCLAB), neither satisfied nor dissatisfied with it, or dissatisfied with it? (1-Extremely Satisfied,..,7- Extremely Dissatisfied); (C) Overall, how much have hands-on activities in the CVCLAB contributed to your learning in this course? (1-Extremely Contributed,..,7-Not contributed at all); (D) How easy or difficult has it been for you to complete exercises in CVCLAB? (1-Very Easy,..,7-Very Difficult).

The results in Table II indicate that students who found the activities easy to complete were less positive about the benefit of team activities. On the contrary, students who had difficulty in completing hands-on activities were more supportive of team activities (the correlation between the perceived difficulty of the activities and the average support of team-labs was 0.53 -Pearson correlation significant at the 0.01 level). This observation may suggest that students who lacked some technical skills benefited from peer-scaffolding [9], but skilled students considered team labs as a burden as discussed in the following section.

Overall, students were overwhelmingly supportive of the delivery model of the course, and the majority strongly agreed that the course provided as many hands-on experiences as a traditional course (as seen in Table I).

TABLE II
CORRELATIONS BETWEEN TEAM-LAB SUPPORT, SATISFACTION WITH THE CVCLAB, IMPACT OF HANDS-ON LEARNING, AND DIFFICULTY OF HANDS-ON ACTIVITIES (* INDICATES PEARSON CORRELATION SIGNIFICANT AT THE 0.01 LEVEL)

	(A)	(B)	(C)	(D)
(A) Team-lab support		0.58*	0.17	0.53*
(B) Overall satisfaction with the CVCLAB			0.71*	0.32
(C) Perceived contributions of hands-on activities to learning				0.11
(D) Perceived difficulty of hands-on activities				

Students overwhelmingly agreed that the hands-on activities contributed significantly to their learning experience and found section reading and instructor feedback more valuable than animations and video clips. Again, as stated, although the course was asynchronous and there was no regular class session, the instructor held online office hours and was able to remotely help students when they needed them. Fig. 2 summarizes the students' score about how much the various components of the course delivery model contributed to their learning.

Discussion boards were identified as the least effective component of the delivery model. The course had a general discussion board in which students were expected to discuss various aspects of the course topics (e.g., review questions at the end of each section, hands-on activity questions, etc.). Students were encouraged to post questions and to help one another through the course discussion board as well as being expected to post comments to respective discussion forums as required by certain assignments. Over the course of the semester, while some students used the general course discussion board frequently, many students chose not to participate at all. When students were asked to rank the components of the course delivery model in terms of their contribution to learning, hands-on activities, section readings, and instructor feedback/help came out be the first three factors, respectively.

V. DISCUSSIONS

Based on the student feedback, our findings related to the three research questions are summarized as follows:

1) Can a VCL be used in an online, asynchronous course to provide distance learning students with rigorous and comprehensive hands-on learning experiences?

The answer to this question is a definite YES. The CVCLAB enabled students to perform complex and rigorous tasks remotely with students consistently rating the hands-on component of the courses very highly.

2) Which competent of the online delivery model has the most positive impact on student learning?

With an emphasis on experiential learning, hands-on activities clearly had the most positive impact on students' perceived

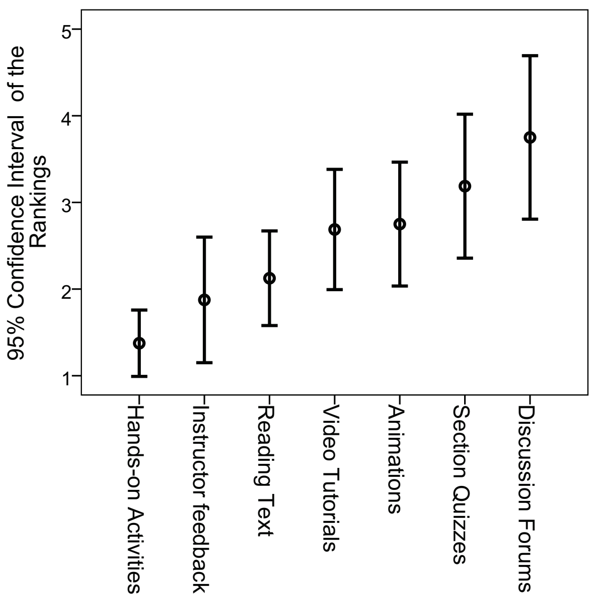

Fig. 2. Student evaluations of the components of the delivery model (Question: Please indicate how much the following course components has contributed to your learning in this course (1-Extremely Contributed , 7- Not Contributed at all)

learning. Reading materials were found as the second most useful component. Further, students agreed that animations and video clips contributed positively to their learning (between very much and moderately contributed in Fig. 2), but rated reading materials higher. We attribute this result to two reasons. First, most of the text content was organized around hands-on activities which put reading materials into a practical context. Secondly, while multi-media is effective in introducing a new topic to students, it is not very convenient for revisiting concepts as in the case when students must review the material for quizzes or hands-on activity reports. Although the course was asynchronous and did not include any lectures, students valued the interaction with, and feedback from, the instructor. This suggests that instructors also play an important role in asynchronous online courses although they are not directly involved in the content delivery.

3) In asynchronous hands-on distance learning, if collaborative learning strategies are implemented in a VCL, can student learning be enhanced well beyond enriching content delivery?

Logistical and technical challenges of performing teamwork remotely diminished the pedagogical value of collaborative learning in the course. Clearly, better strategies and approaches are required to incorporate collaborative hands-on activities into asynchronous distance learning courses. There are a number of challenges associated with teamwork in e-learning [10]. However, these challenges are worth overcoming due to the numerous benefits stemming from the teamwork experience in general.

The foremost challenge is the communication. One of the reasons students take online courses is that they would like to have more flexibility in their use of time. This needs for more flexibility in scheduling also lead to difficulties in arranging meetings among team members. Finding a common time, even for an online meeting, when everyone is available is a challenge. An alternative is an asynchronous mode of communicating with others. However, the downside of this approach is the time delays in the communication itself [11]. For example, a student cannot make any more progress with an assignment until the partners of the team respond to an email asking for information or tasks to be done.

Another challenge of group work in e-learning is planning overhead. The difficulty in communicating with people also contributes to the increased planning overhead. It turns out that there is a significant presence of planning activities within group interactions, the extent of which seems to be related to communication limitations [12].

The lack of Challenge and Explain Cycles is also another disadvantage of group work in e-learning. One of the advantages of face-to-face interactions over their online counterparts is that the former facilitates the challenge and explain cycle [13]. In an ideal team setting involving face-to-face interactions, a team member with an opposing view will challenge the other members with questions. The process of asking these questions and responding to them often helps the team reach a consensus. This consensus-building process encourages the reconceptualization of prior knowledge, motivation to learn, curiosity, high quality decision making, insight into the problem, higher-level reasoning, and cognitive development [11]. Curtis and Lawson [12] point out that there is a lack of challenge and explain cycle due to the nature of online collaborative learning.

Once the aforementioned challenges are removed, group work in an e-learning environment can benefit from the well-known advantages of collaborative learning [14]. Some of the advantages of collaborative learning include: creating an environment of active, involved, and exploratory learning, encouraging diversity understanding, enhancing student satisfaction with the learning experience, promoting positive attitude toward the subject matter, developing social interaction skills, using a team approach to problem solving while maintaining individual accountability, encouraging student responsibility for learning, enhancing self management skills, etc.

VI. CONCLUSIONS

In this paper, we presented an asynchronous online delivery model for information security courses. The delivery model attempts to address the question of whether rigorous hands-on education/training is possible in information security or not. The preliminary data showed that students considered the delivery model as effective as a traditional course. However, the collaborative aspect of the delivery model was not well received by students. As future research, effective ways for online collaborative hands-on activities will be investigated.

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