Journal of Information Processing Vol.21 No.1 67–74 (Jan. 2013)

[DOI: 10.2197/ipsjjip.21.67]

Regular Paper

Collaborating Remote Computer Laboratory and Distance Learning Approach for Hands-on IT Education

Patcharee Basu[1,a)] Achmad Basuki[2,†1,b)] Achmad Husni Thamrin[2,c)] Keiko Okawa[2,d)] Jun Murai[2,e)]

Received: March 19, 2012, Accepted: October 10, 2012

Abstract: This paper studies the innovative methodology for developing IT education from the traditional face-to-face model to full capability of distance learning by combining a remote computer laboratory and a distance e-learning environment. There are three approaches presented with different implementations of laboratory technologies and learning models. The design challenge is to address the limitations of resources at region-wide learning sites, cost-effectiveness and scalability. Computer virtualization and StarBED computing testbed can achieve a larger scale of laboratory size with less cost of equipment and administration workload. The live learning environment ensures quality of realtime communications during lecture and lab sessions by employing IPv6 Multicast on a satellite UDLR network. The self-paced learning environment is proposed to enable a flexible schedule, resource reusability, and scalability. The lab supervision system is the key component to enhance teaching effectiveness in the self-paced hands-on practice by systematically automating the lab supervision skills of lecturers. These approaches have been evaluated as feasible, cost-effective and scalable by the real implementations of similar Asia-wide workshops. Trade-off overheads and analysis on technology and pedagogy perspectives are made to compare their characteristics.

Keywords: distance learning, e-learning, remote computer laboratory, hands-on IT workshop, IT education

1. Introduction

The increasing demand for IT human resources becomes crucial for socio-economics development, especially in developing regions. IT education requires both theoretical and practical knowledge to develop full comprehension. However, one of the primary barriers is the fundamental problem of resource limitation, particularly a lack of experienced teachers and laboratory facilities.

Distance e-learning is widely deployed to support learning activities by digital and communication technologies. For IT education, it is useful to overcome the shortage of teachers but the traditional distance e-learning lacks the capability of supporting IT hands-on lessons. Therefore, it is necessary to research for alternative methodologies which disseminate IT knowledge with hands-on practice in a cost-effective and timely manner.

This paper presents an educational development to implement a region-wide hands-on IT education environment by combining remote computer laboratory and distance e-learning to achieve the cost-effectiveness and scalability. The design challenge is to deliver knowledge to learners in developing regions by taking into consideration the shortage of equipment and also the limited capacity of the Internet to access a remote system. In particular, the contributions of this paper are 1) It studies several approaches to accomplish the same goal by using different combinations of remote laboratory technologies and distance e-learning models. The cost-effectiveness of these approaches is compared to the traditional face-to-face approach based on the real implementations of similar IT trainings. 2) It proposes an innovative approach of a self-paced learning model with an automated lab supervision system to achieve higher resource utilization and scalability. 3) It provides a comparison analysis of the advantages and disadvantages found in different approaches.

The study is carried out on the School on Internet Asia project (SOI Asia)'s [1] IT operator workshops from 2005–2010, region-wide IT engineers participated in intensive hands-on workshops to learn to operate the project's local network and systems. The face-to-face workshop was not scalable due to the high cost as explained in Section 3. Therefore, distance e-learning was implemented by the three different approaches being developed from 2006 as shown in **Table 1**. As a remote computer laboratory, computer virtualization and StarBED computing laboratory are the two technologies applied, as explained in Section 4. Section 5 presents the live and self-paced distance e-learning environments that fulfill the lecture and lab supervision activities. In Section 6, the cost-effectiveness of the three approaches is evaluated, compared to the face-to-face workshop, and their different aspects are analyzed.

1 Keio Research Institute at SFC, Fujisawa, Kanagawa 252–0882, Japan
2 Keio University, Fujisawa, Kanagawa 252–0882, Japan
†1 Presently with Universitas Brawijaya
a) yoo@sfc.wide.ad.jp
b) abazh@ub.ac.id
c) husni@sfc.wide.ad.jp
d) keiko@kmd.keio.ad.jp
e) junsec@sfc.wide.ad.jp

Table 1 Different workshop approaches being studied.

Year	Approach name	Remote computer lab and distance e-learning environment
2006	VL	Computer virtualization and Live distance e-learning
2008	SL	StarBED computing laboratory and Live distance e-learning
2010	VS	Computer virtualization and Self-paced distance e-learning

Table 2 Related works in IT hands-on education.

	Lab platform	Lab scheduling / Archive	Distance / E-learning	Hands-on super-vision
VCL [3]	PM,VM /VCL [3]	Auto /Yes	- /-	Human
Edubase [2]	VM /eucalyptus [26]	- /Yes	- /-	Human
Nieh et al. [22]	VM /VMware [4]	- /-	Yes /-	Human
Rigby et al. [23]	VM /Windows [27]	Auto /No	Yes /-	Human
VL [9]	VM /VMware[4]	Manual /No	Yes /Live	Human
SL [11]	PM /SpringOS [19]	Manual /No	Yes /Live	Human
VS	VM /KVM[20]	Auto /Yes	Yes /Self-paced	Auto-mated

PM = Physical machines.
VM = Virtual machines.

2. Related Works

Cloud and computer virtualization have been practically deployed in education to implement configurable remote computer laboratories in a cost-effective way, as example works shown in **Table 2**. NCSU Virtual Computing Lab (VCL) [3] is, an open-source platform to build a private cloud over distributed data centers in educational institutions, being used in the Academic Cloud Computing Initiative (ACCI). Edubase cloud [2] is an application in IT professional training to build alterable labs on cloud.

With the remote lab capability, the development of new pedagogies to conduct teaching/learning in an IT course could be enhanced to distance learning [22], [23] to improve educational scalability. The VL [9] and SL [11] approaches incorporate a live distance e-learning environment to accommodate distributed learning sites. However, an IT hands-on course generally has a class size versus efficiency concern because it depends on human instruction. The VS approach proposes self-paced on-demand learning with an automated lab supervision system. It lessens instructors' workloads, shortens learning time and increases content utilization.

3. The Face-to-face Workshop

The traditional approach of IT hands-on education is the face-to-face model (F2F). Class members, including lecturers, teaching assistants (TAs) and learners are at the same location with laboratory facilities. In SOI Asia project, the F2F workshops were held annually from 2002–2005. Lecturers and participants traveled to the venue for a 5–7 day training program. Physical laboratory equipment in proportion to the number of participants

Table 3 Workshop curriculum and lab scenarios.

Lab	Hands-on exercises	OS and lab topology
1	Routing IPv6network - Set hostname, IPv4/IPv6 forwarding - Quagga for OSPFv3 unicast routing - XORP for PIM-SM multicast routing	FreeBSD 4.9 (F2F), 6.1 (VL), 6.2 (SL), Fedora10 (VS) (1-2 LAN topology)
2	UDLR config: set NAT for GRE - static route to UDLR feed	OS same as Lab 1 (1 topology to Internet)
3	DNS,Totd,RA,DHCP,Cache proxy HTTPD, Net-snmp, MRTG, SSMPing SOI Asia Multicast file transfer, Video streaming	FedoraCore4 (F2F, VL) FedoraCore6 (SL) FedoraCore10 (VS) (1 topology to Internet)

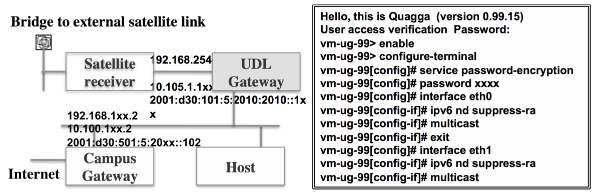


Fig. 1 Lab 2 topology and hands-on exercise example.

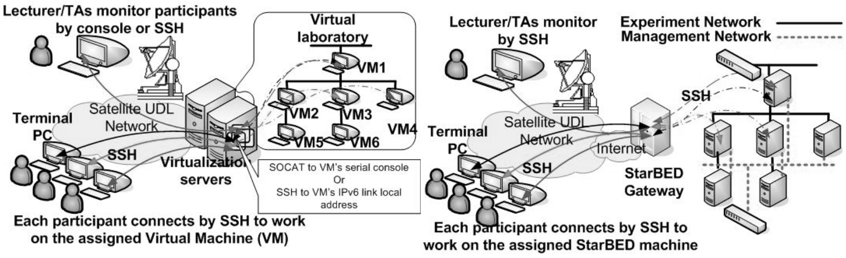
were arranged by purchase, rental or loan. Laboratory administration tasks to prepare equipment according to the lab designs were carried out manually.

The advantage of this approach is that learners can obtain full practical experience of both logical operations on software and especially physical manipulations on hardware. Lecturers can closely instruct lab exercises and control the pace of teaching. Learners also developed interpersonal relationships with other class members. However, with an increasing number of participants over the years, it is not scalable due to the high cost of 1) travel, 2) laboratory equipment and 3) the human workload to administer the large laboratory size. Therefore, the distance e-learning approach is proposed to deliver workshop to region-wide learners with less resource required.

4. Remote Computer Laboratory

In addition to the fundamental requirement to support lecturers' lab designs including hardware specifications, OS, applications and network topologies, the remote computer laboratory must possess two main qualities: 1) Its functionality to support hands-on exercises from remote learners and support remote monitoring/laboratory administration from lecturers and TAs. The design must take into consideration the limited equipment/Internet bandwidth at learner sites. 2) Its scalability to accommodate a larger laboratory by efficient lab management in which the integrity of lab configuration is high.

This study has experimented with both virtual computer laboratory and physical computer laboratory as explained in Section 4.1 and Section 4.2 respectively. Each was applied in different workshop approaches to implement the curriculum in **Table 3**. Lab network topology changes according to lessons and it may require an Internet connection. In each lab lesson, a learner is instructed to configure one computer in the lab topology to run the required services. **Figure 1** shows a lab scenario and a sample hands-on exercise in which a learner configures a machine called UDL gateway to route IPv6 traffics from a satellite link to a local network.



Computer virtualization laboratory StarBED physical laboratory

Fig. 2 Remote computer laboratory platforms.

Table 4 Implementation details of virtual computer laboratory.

	Platform	Specifications	#Server/#VMs per server	#learners/ period
VL	VMWare [4]	Celeron Dual-Core 3.0 GHz, 1 GB RAM (minimum spec)	6 /6-12	42 /5
VS	KVM [6]	Intel Core i7 2.67 GHz, 6 GB RAM	2 /8-28	31 /10

4.1 Computer Virtualization Technology

Computer virtualization is widely used to run a number of virtual machines (VM) with desired specifications on a physical server running a virtualization software/hardware platform. **Figure 2** illustrates the virtual computer lab environment, a number of virtualization servers were prepared at the lecturer site according to details in **Table 4**. For a remote lab exercise, each learner connects to a virtualization server by SSH and runs a script to connect to the assigned VM. The script accesses to VM console by socat [5] or SSH to the VM's IPv6 link-local address because of lower bandwidth consumption compared to the graphic console access applications [8]. A basic terminal PC is required for each learner (Pentium 800 Mhz, 256 MB RAM). For lab monitoring and administration, lecturers and TAs could access a VM console to manipulate VMs and monitor learners' activities. Lab preparation is convenient compared to manual administration of the same number of physical computers because the process is computerized. Lab scenarios are created by producing a master VM from the requirement and copying identical VMs for the rest. This technique requires less human workload to create a laboratory environment and to ensure its integrity.

4.2 StarBED Computing Laboratory

StarBED [19] is a large-scale computing testbed consisting of 680 high-performance computers and network switch clusters to create the desired network topologies. It provides a realistic testbed with flexible management. In deployment of the SL approach, a cluster of 67 StarBED nodes (Pentium4 3.2 GHz, 8 GB RAM) were allocated to train 42 participants in 5 days. Each learner was assigned one StarBED node and connected to the node by SSH through the StarBED gateway as shown in Fig. 2. In order to separate experiment and control data, one network interface of each node is dedicated for remote access and the others can be used for lab purposes. Lab preparation is carried out by creating a master copy of a lab machine and duplicating the disk image to other machines by an automated process. Different lab topologies are created on a switch cluster by VLAN configurations without physical topology intervention. The lab management system ensures the integrity and reduces the installation time of many physical computers. Lecturers access the console and manage power by KVM-over-IP [20] and IPMI [21] respectively.

5. Distance E-learning Environment

In an IT hands-on workshop, class activity is usually comprised of lecture sessions for theoretical concept and lab sessions for hands-on experiment. The communication in a lecture session aims to deliver a set of knowledge to all students. On the other hand, the communication in a lab session pays attention to individuals to guide them through lab exercises. This paper presents live and self-paced distance e-learning environments to implement these communication characteristics in IT hands-on education.

5.1 Live Distance E-learning Environment

The live learning model emphasizes on realtime interactivity among class members at different locations. The key challenge is to ensure the quality of communications. Therefore, the environment design utilizes the network infrastructure and technologies proposed by Ref. [10] to overcome the known problem of inadequate Internet quality in Asia. As shown in **Fig. 3**, a unidirectional broadcast satellite link called the satellite UDL, delivers traffics to region-wide learner sites. Each learner site uses the local Internet to send data back. Unidirectional Link Routing (UDLR) [14] emulates bidirectional connectivity between the satellite hub station, called the gateway site, and learner sites. IPv6 Multicast is deployed to optimize bandwidth consumption on the satellite UDL when transmitting data to many receivers. A lecturer site can be at any location provided that there is a high-speed Internet connectivity to the gateway site which will relay lecture traffics to all learners.

Applications in the live distance e-learning environment [12] supports live multi-site conversations in the form of video, audio, text, presentation, and lab demo, as shown in Fig. 3. The design intends to keep costs low at learner sites, therefore the required applications are mostly open-source or self-developed operating on either PC-based Unix and Windows (1 GHz CPU, 512 MB RAM). VIC/RAT [15]/VideoLAN [16] support IPv6 Multicast to save bandwidth on the satellite UDL. A lecturer site may use different applications (DVTS [24], H.323 [25]) which the gateway site receives and relays to the applications/bandwidth appropriate for learner sites, and vice versa. LivePresenter was developed

Journal of Information Processing Vol.21 No.1 67–74 (Jan. 2013)

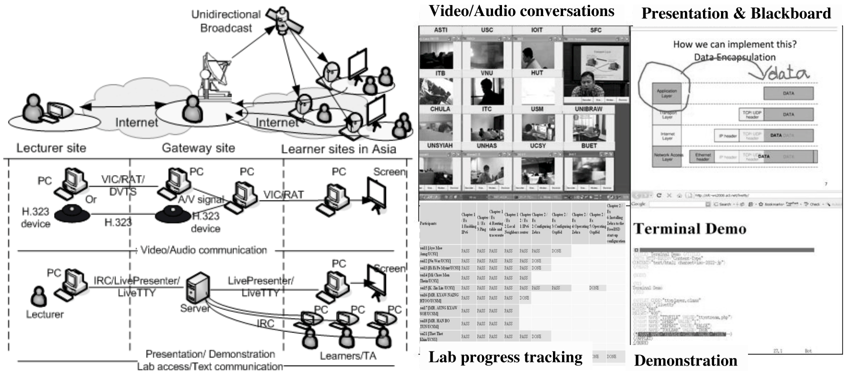


Fig. 3 Live distance e-learning environment.

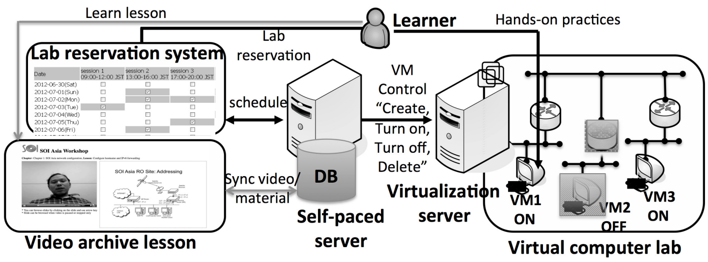


Fig. 4 Lesson and lab control system in the self-paced environment.

to share synchronized views of slides with animations and handwriting through the web browser's flash plug-in. LiveTTY was developed based on TTYPlayer [18] to share live demo of Unix-based terminal on web browser. LabPG was developed to check the learners' work status since the traditional verbal check was found ineffective in a remote environment. A set of checkpoints on hands-on tasks has been defined by lecturers prior to the workshop. During the class, a learner constantly reports the completed exercises. Local TAs verify the learner's works and approve the reported status. The lecturer checks the status and determines the teaching pace accordingly.

5.2 Self-paced Distance e-learning Environment

The self-paced environment is the latest development proposed in this paper to support an alternative learning method. The inflexibility of time and the class-size versus efficiency issue are the two major concerns when the workshop is delivered in realtime. Therefore, the self-paced learning emphasizes flexible time management and workshop resource utilization. The key challenge to realize a self-paced hands-on workshop effectively is the ability for learners to carry out hands-on exercises with less human intervention. Therefore, it is necessary to design a lab supervision system which turns lecturers' lab supervision skills into an automated system.

The proposed environment comprises (i) Lesson and lab control system, (ii) Lab supervision system. The lesson and lab control system provides the necessary components for a learner to learn lessons and carry out hands-on exercises. As shown in **Fig. 4**, the self-paced server is a center which synchronizes all activities. A learner can access the video lessons stored in the database anytime. In order to share the virtualization server's resources more effectively, lab sessions need to be reserved in advance and only the VMs in use will be turned on in each period. The self-paced server creates an image copy of the lab scenario for each learner at the first use, controls on/off scheduling of the VMs set and deletes the image when the workshop is over.

The lab supervision system is a core function to realize self-paced learning. The process to identify problems, give instructions and confirm the result, is turned into an automated system in order to guide learners to carry out lab exercises on their own as much as possible. As shown in **Fig. 5**, a lecturer creates a lab supervision flow for each exercise to define a step-by-step action which identifies the status whether it succeeds or fails. For failed cases, the possible sources of the problem are identified. The flow design requires the lecturer's experiences and troubleshooting skills in the taught lesson. This flow is compiled accordingly to a script and loaded on each VM. When a learner wants to verify the exercise, an embedded button on the web lesson is clicked. The automated lab supervision process on the self-paced server then calls the associated script and returns the checked result onto the web. The learner repeats the process again after trying to fix possible problems on the VM. In the cases that need human supervision, the learner can contact local TAs personally or make an appointment with the lecturer. Email or the live communication system in Section 5.1 can be utilized for the consultation. With the ability to verify and record the status of each lab exercise systematically, it is more accurate to observe learners' work progress and to evaluate workshop completion for the purpose of certification or accreditation.

The proposed environment is suitable for a large scale workshop in terms of schedule arrangement for class members and the diverse skills of learners. It could be utilized conveniently for subsequent training needs.

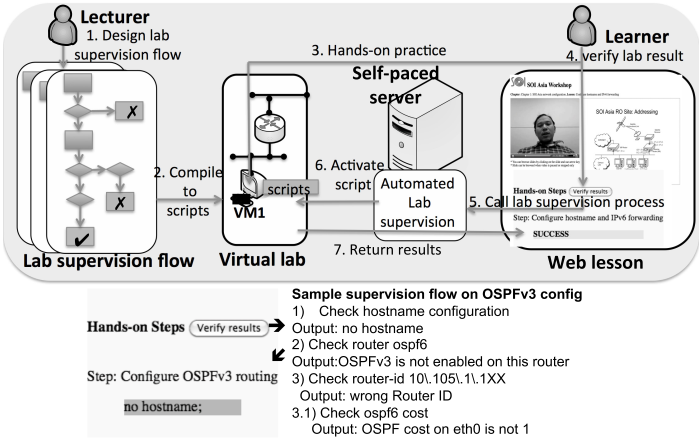


Fig. 5 Lab supervision process and the user interface showing the missing configuration.

6. Analysis and Evaluation

This paper studies the three approaches in Table 1 to realize region-wide IT hands-on education by integrating a remote computer laboratory with a distance e-learning environment as an alternative educational method to the face-to-face approach. The evaluation and analysis is made based on the data collected from the real implementations, questionnaire results from learners, lecturers and organizers. This section discusses the overall cost-effectiveness and trade-off overhead compared to the face-to-face approach and makes a detailed analysis to compare these approaches in perspectives of a remote computer laboratory, a hands-on e-learning environment and scalability.

6.1 Cost-effectiveness Analysis

The VL, SL and VS approaches have proven to achieve their goal to educate region-wide IT human resources from the comparable number of participants to the F2F approach as shown in **Table 5**. The overall workshop effectiveness to achieve its training goals was evaluated positively from the questionnaires returned by learners as shown in **Table 6**.

Table 5 Implementation data of different workshop approaches.

Approach	F2F	VL	SL	VS
Year	2005	2006	2008	2010
Workshop period	5 days	5 days	5 days	10 days
#Participants	33	42	42	31
#Participant sites	1	16	15	12
#Lecturers	3	4	6	3
#Lecturer sites	-	1	5	-
#Travels[international /domestic]	[37/0]	[3/5]	[0/3]	[0/0]
#Physical machine	40	6	67	2
#Lab deployment time	120 hours [9]	600 seconds [8]	2,552 seconds [11]	16 second per VM
#TAs[local/ remote]	[8/0]	[23/8]	[24/5]	[20/2]

Table 6 User evaluation on workshop effectiveness and lab response time.

	Approach	Positive	Fair	Negative
Workshop effectiveness	VL	95%	5%	0%
	SL	91.7%	8.3%	0%
	VS	95%	5%	0%
Lab response time	VL	60%	20%	16%
	SL	100%	0%	0%
	VS	75%	20%	5%

Travel cost: The F2F approach had very high travel costs as there were 37 international journeys in 2005. The distance e-learning approaches reduced the number of journeys significantly as shown in Table 5. Because of a fixed workshop period, both the VL and SL approaches still require travels to place staff at some learning sites where there is no qualified TA to facilitate the workshop. There is no travel required in the VS approach because the period is determined by the learners' readiness.

Laboratory cost: The laboratory cost is comprised of equipment cost and lab administration workload. The lab administration includes the preparation of the master machine which was estimated as 1–4 hours in all approaches and the lab deployment time to copy the master to the rest of the lab machines. The virtual computer laboratory in the VL and VS approaches is most economical from the significantly reduced number of machines and the much lower deployment time as shown in Table 5. The number of physical machines in the F2F and VS approaches is proportional to the number of participants, however the VS approach yielded considerably shorter lab deployment time by making use of an automated lab setup. Therefore, the laboratory cost in the VL, SL and VS approaches is lower compared to the F2F approach.

Lesson preparation cost: The lesson preparation cost includes both theory and hands-on lessons, but not the lab preparation which is already discussed in the laboratory cost. From lecturers' opinions, the preparations were not different in the F2F, VL and SL approaches because the learning model is similar. For the VS approach, there is approximately 4 times the workload in the hands-on lesson preparation for additional steps to prepare supervision flow, scripts and test. However, this function reduces the lecturers' workload during the learners' hands-on exercises compared to the other approaches.

Learning site cost: The overheads are the local TAs, PC terminals and the local distance e-learning environment. In the SOI Asia implementation, it required one TA per 3 learners at every site. With the highly distributed environment as there were 12-16 learning sites, more TAs were involved as shown in Table 5.

Table 7 Remote computer laboratory in different workshop approaches.

Approach	F2F	VL	SL	VS
Physical machines	$N + E$	$(N + E)/V$	$N + E$	$((N + E)T_L)$ $/(VT_{SP})$
Terminal PC	0	N	N	N
Lab deployment time	MN	$M + \alpha N$	$M + \mu N$	$M + \alpha N$
Integrity	Medium	High	High	High
Hardware fault	High	Low	High	Low
System load	Low	High	Low	Medium
Hardware lesson	Yes	No	No	No

M = Time to prepare a lab master machine.
N = Number of participants.
α = Average time to duplicate one VM from master image.
μ = Average time to copy master disk image to one StarBED node.
E = Extra machines for lecturers, spares, etc.
V = A number of VMs hosted in a virtualization server.
T_L = Length of live workshop period.
T_{SP} = Length of self-paced workshop period.

The workload of TAs in the VS approach is lower because the supervision duty is partially taken by the lab supervision system.

6.2 Analysis of Remote Computer Laboratory

In addition to the total laboratory cost, this section discusses other important aspects of the remote computer laboratory deployed in different approaches as shown in **Table 7**. The VL approach reduces the equipment cost compared to the F2F and SL approaches because a physical machine can host a number of VMs. However the VS approach can save more equipment cost because the self-paced workshop usually has less restriction in time and can run longer than the other approaches. With an efficient lab scheduling mechanism to share servers' resources, the equipment cost decreases in proportion to the length of workshop period. In terms of lab administration, the automated process in the VL, SL and VS approaches not only tremendously reduces the administration workload as demonstrated in Table 5, but also maintains high lab integrity. Therefore, they can achieve a higher scalability in terms of laboratory size. Nonetheless, there are more possibilities of hardware faults in the VS approach since there are a greater number of machines to be maintained.

Lab response time is a concern when deploying computer virtualization. As shown in Table 6, learners reported a slow response time in the VL and VS approaches. The average CPU utilizations measured in the SL approach were low, 0.63% and 0.59% for FreeBSD and Fedora6 respectively [11]. The CPU utilization of a virtualization server were 30% running 6 FreeBSD VMs and 10% running 6 Fedora4 VMs in their idle states, and reached 90% during some peak periods in VL approach [8]. Lab response time of the VS approach is better than the VL approach because there is a lower chance that learners activate heavy processes at the same time in the self-paced learning.

6.3 Analysis of the Live and Self-paced Distance E-learning

This section evaluates both distance e-learning environments according to its objectives to support lecture and lab supervision activities. The live distance e-learning environment deployed in the VL and SL approaches focuses on the quality of live conversations among region-wide distributed sites. It has proven the ability to support a large number of sites concurrently as there were 16 and 20 sites including lecturer and learner sites as shown in Table 5. The satellite UDLR network was measured [10] to deliver better quality streams with lower data loss/jitter and a more stable rate. For the 512 kpbs UDP stream to 9 receiving sites measured in 2 hours [10], the average data loss rate was 0.0052–0.0077% on the satellite UDL and 0.18–84% on regular Internet. The satellite bandwidth was utilized 4–8 Mbps [11] in the SL approach for 42 participants from 15 sites. Participants evaluated the qualities of communications including video, audio, text, live presentation, and live demonstration as satisfactory from relatively positive feedbacks [12].

For the self-paced distance e-learning environment, the learning effectiveness depends on the quality of video lessons and the ability of the lab supervision system to guide them in hands-on exercises. In the VS approach deployment, learners could decide the place and time to study, hence the experiences on the video lesson depend on their Internet quality. From the open-ended questionnaire returned by 22 out of 31 participants, 80% found the quality of the video/audio lessons was adequate for their studies. There were in total 29 hands-on exercises and 95% of the learners evaluated that the lab supervision function was useful to guide them, particularly when facing errors. Lecturers' comments found the lab supervision system reduced their workload to instruct many learners in the long term and it was worth putting in extra effort to produce supervision flows and scripts for lab lessons at the beginning.

In both live and self-paced models, the local TAs play a key role by overseeing the local workshop activities and by assisting learners directly on behalf of lecturers. Questionnaire results of the VL, SL and VS approaches show that learners found their local TAs to be very supportive. A pre-workshop TA training session improves TAs ability to supervise local participants.

6.4 Scalability

Although the design of the VL and SL approaches can accommodate more participants, the common issue of class-size versus efficiency is concerned as similar to the F2F. Within a limited time, a lecturer can effectively instruct only a certain number of learners, especially in the hands-on case which requires individual coaching. Workshop resources in the VS approach can be utilized for subsequent training in a timely manner and can accommodate more participants in the long term compared with the VL, SL, and F2F approaches. The VS environment was utilized 5 more times in 2011 to train 15 staff without lecturers' extra workload because of its automated lab supervision capability.

7. Conclusion

The proposed model to combine a remote computer laboratory and a distance learning environment has enhanced IT education to achieve a higher level of time and location flexibility. The live distance e-learning approaches being studied in this paper provide full class interactivity by addressing the real problems of limited resources/Internet at learning sites. For the proposed self-paced learning approach, the hands-on practice is realized by the automated lab supervision system. The hybrid model is also a promising method to gain the benefits of both learning approaches. A remote computer laboratory implemented by computer virtualization technology is cost-effective and flexible for hands-on lab designs. StarBED computing laboratory is appropriate for high computing hands-on experiments.

Applying the proposed model to IT professional training, distance IT hands-on courses can be developed to accommodate a high demand of IT training from remote participants in a cost-effective and timely manner. With the fast advancement of IT technologies, it could be utilized to improve the problem of the technology gap in different parts of the world. The technology and pedagogy aspects of different approaches discussed in this paper can be useful to the future deployments based on the training contexts.

References

[1] Mikawa, S., Basu, P., Tsuchimoto, Y., Okawa, K. and Murai, J.: Multilateral Distance Lecture Environment on the Internet for Asian Universities, *JSISE*, Vol.5, pp.84–93 (2006).
[2] Yokoyama, S., Yoshioka, N. and Shida, T.: Edubase Cloud: Cloud platform for cloud education, *Edurex12*, pp.17–20 (2012).
[3] Vouk, M.A., Rindos, A., Averitt, S.F., Bass, J., Bugaev, M., Kurth, A., Peeler, A., Schaffer, H.E., Sills, E.D., Stein, S., Thompson, J. and Valenzisi, M.: Using VCL technology to implement distributed reconfigurable data centers and computational services for educational institutions, *IBM J. RES. and DEV.*, Vol.53, No.4, pp.509–526 (2009).
[4] VMWare, available from ⟨http://www.vmware.com/⟩.
[5] Socat, available from ⟨http://www.dest-unreach.org/socat/⟩.
[6] KVM, available from ⟨http://www.linux-kvm.org/⟩.
[7] Mikawa, S., Basu, P., Okawa, K. and Murai, J.: An Asia-Wide Realtime Distributed Hands-On Workshop, *SAINT07 Workshop*, 41, pp.41–44 (2007).
[8] Basuki, A., Thamrin, A.H., Okawa, K. and Murai, J.: A Remote Hands-on Exercise Environment for an Asia-Wide Real-Time Workshop, *SAINT07 Workshop*, 38, pp.38–40 (2007).
[9] Basu, P., Mikawa, S., Basuki, A., Thamrin, A.H., Okawa, K. and Murai, J.: Combination of Online Virtual Computer Laboratory and Region-wide Distance Learning for IT Education in Asia, *EdMedia2007*, pp.1261–1269 (2007).
[10] Basu, P., Thamrin, A.H., Mikawa, S., Okawa K. and Murai, J.: Internet Technologies and Infrastructure for Asia-Wide Distance Education, *SAINT07*, 3, pp.3–10 (2007).
[11] Basu, P., Mikawa, S., Basuki, A., Thamrin, A.H., Okawa K. and Murai, J.: An Asia-wide Distributed Hands-on Workshop: Synchronous Learning and Large-scale Computing Laboratory, *CATE08*, pp.166–171 (2008).
[12] Basu, P., Mikawa, S., Basuki, A. and Okawa, K.: An Educational Development on Learning Paradigm of Region-wide IT Hands-on Workshop, *KEIO SFC JOURNAL*, Vol.8 No.2, pp.59–75 (2008).
[13] Basu, P., Mikawa, S., Basuki, A., Thamrin, A.H., Okawa K. and Murai, J.: Distance Learning Computer-based Hands-on Workshop: Experiences on Virtual and Physical Lab Environments, *DLI08*, pp.5–2 (2008).
[14] Duros, E., Dabbous, W., Izumiyama, H., Fjuii, N. and Zhang, Y.: A Link Layer Tunneling Mechanism for Unidirectional Links, *RFC 3077* (2001).
[15] Perkins, C., Hardman, V., Kouvelas, I. and Sasse, A.: Multicast Audio: The Next Generation, *INET97* (1997).
[16] McCanne, S. and Jacobson, V.: vic: A Flexible Framework Framework for Packet Video, *ACMMM95*, pp.511–522 (1995).
[17] Oikarinen, J. and Reed, D.: Internet Relay Chat Protocol, *RFC 1459* (1993).
[18] TTYPLAYER, available from ⟨http://www-masu.ist.osaka-u.ac.jp/~kakugawa/misc/ttyplayer/index-en.shtml⟩.
[19] Miyachi, T., Chinen, K. and Shinoda, Y.: StarBED and SpringOS: Large-scale General Purpose Network Testbed and Supporting Software, *ValueTools06* (2006).
[20] Raritan Inc., available from ⟨http://www.raritan.com⟩.
[21] Intel Corporation, IPMI v2.0 specifications.
[22] Nieh, J. and Vaill, C.: Experiences teaching operating systems using virtual platforms and Linux, *ACM SIGOPS OSR*, Vol.40, No.2, pp.100–104 (2006).
[23] Rigby, S. and Dark, M.: Designing a flexible, multipurpose remote lab for the IT curriculum, *SIGITE06*, pp.161–164 (2006).
[24] Ogawa, A., Kobayashi, K., Sugiura, K., Nakamur, O. and Murai, J.: Design and implementation of DV stream over Internet, *IWS99*, pp.255–260 (1999).
[25] Packet-based multimedia communications systems, available from ⟨http://www.itu.int/rec/T-REC-H.323-200606-I/en⟩.
[26] Eucalyptus, available from ⟨http://www.eucalyptus.com/⟩.
[27] Windows virtual PC, available from ⟨www.microsoft.com/windows/virtual-pc/⟩.

Patcharee Basu is a researcher at Keio Research Institute at SFC. She is a graduate from the Asian Institute of Technology (M. Eng in 2001). Her research interests are Distance E-learning, IPv6 and Multicast.

Achmad Basuki is a full-time lecturer at the Universitas Brawijaya, Indonesia. He is a graduate of Keio University, Graduate School of Media and Governance (Ph.D. in 2012, MMG in 2008). His research interests include multimedia networking, overlay networks, and data center networking.

Achmad Husni Thamrin is a project assistant professor at Keio University. He is a graduate of Keio University, Graduate School of Media and Governance (Ph.D. 2005, MMG, 2002). His research interests include multicast, Internet over broadcast media, distance education and peer-to-peer networks.

Keiko Okawa is a professor at the Graduate School of Media Design, Keio University (KMD). She received her Ph.D. in Media and Governance from Keio University in 2001 and a master degree in engineering from Keio University in 1985. She has been serving as a director of the "SOI Asia project" since 2001 and is currently leading the Global Education Project at KMD focusing on research in globalization of the education and global citizenship education, utilizing ICT.

Jun Murai is a professor at Faculty of Environment and Information Studies, Keio University. He received his M.E. and Ph.D. in Computer Science from Keio University in 1981 and 1987 respectively. He was a director of Keio Research Institute at SFC, the president of Japan Network Information Center (JP-NIC), board director of ICANN. Adjunct Professor at Institute of Advance Studies, United Nation University He also teaches computer network and computer communication.