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# A pedagogical rich interactive on-line learning platform for Network Technology students in Thailand

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## Abstract

Internetworking enables communication between networks and forms the foundation of the Internet. Internetworking teaching is typically conducted in a traditional face-to-face classroom, but nowadays it can be conducted online. Online learning environments have many advantages that include allowing remote students' access to not only curriculum but also lecturers and other enrolled students. However, unlike some other disciplines, teaching internetworking courses online is problematic because students need to be given access to internetworking equipment. It is technically possible to provide remote access to online students in order to compensate for the lack of direct physical equipment access, which normally is offered to traditional students. However the standard method of remote access only provides students with a limited text based method of configuring internetworking devices. Internetwork simulators are of value but they cannot provide students experience working with real devices. A pedagogically rich, interactive on-line learning environment using low-cost, assistive multi-media based technologies was therefore developed. This paper presents details of the platform and results of its deployment from an Australian university to a small group of students in Thailand.

*Keywords*: E-learning, remote access laboratory, network education, internetworking education, State Model Diagram, distance learning, pedagogy

## 1 Introduction

On-line learning, also referred to as e-learning, is an essential part of many modern university courses. This mode of instruction is not only cost effective but it also provides educational opportunities to students on a global scale. Some students, those who are geographically isolated or have competing commitments, for example, might be precluded from a more traditional educational environment. Furthermore, many students have grown up with communication technologies that have influenced their preferred learning style (Dede 2005). The 'net generation' is believed to have developed aptitudes and expectations based upon their daily use of technologies such as email and instant messaging (Gulatee and Combes 2008). On-line curricula typically provide both asynchronous (email, podcasting, discussion boards) and synchronous (instant messaging, voice over IP) methods of communication to students. Online-learning offered alternatives.

### 1.1 Network technology education

Within the field of network technology education, practical, hands-on skills are of paramount importance; particular issues may be arisen with this requirement. Ideally students should be provided with the opportunity to interact with network devices. Hands-on activities are suggested as an important component in learning (DiCerbo 2009). Hands-on workshops not only enhance learning but also provide students with practical skills that are demanded by potential employers. This can also be an important factor in enabling students to obtain initial employment in the industry. In order to provide curricula relevant to employer expectation the world's largest suppliers of network equipment, Cisco, developed the Cisco Network Academy Program (CNAP). CNAP defines the global standard by which students can learn about and be assessed in network technology and is offered in over 11,000 academies in 162 countries with over 500,000 students worldwide. It is the most widely used network curriculum and the international standard by which professional competency can be measured. CNAP regards hands-on skills as a key graduating factor.

In order to build hands-on skills, a proper teaching facility and laboratory equipment is required. Even though low cost network equipment is available to be purchased on CNAP, or second-hand on the internet, network laboratories normally require class sets which incur on-going technical support and maintenance. Such capital expenditure is likely to be beyond the means of many institutions in developing countries.

Various simulation tools can be of use; however, they cannot provide students with the opportunity to interact with actual internetworking devices. Furthermore, simulation results may be limited to the quality of simulation tools, which are not recommended to be used solely as a replacement of the actual laboratory (Cisco 2009).

Hence providing hands-on skills to students via remote access is an important challenge; this in itself includes potential technical problems, namely the bandwidth and reliability of the communication links. While it is possible to provide on-line students with remote access to internetworking devices, users also must interact with actual devices by using only the text-based Command Line Interface (CLI). The CLI is complex, verbose and syntactically difficult to use. CLI uses words to describe the status and behaviour of the laboratory devices. Words, or symbolic description, are the most advanced stage of learning from cognitive revolution theories according to Bruner (1966). Hence, the CLI alone may be unsuitable to be utilised as an educational tool, as it is intended to be used by experienced professionals in the field.

In order to address the problems of students using the CLI, State Model Diagrams (SMDs) were developed and introduced by Maj (Maj and Kohli 2004). SMDs are a diagrammatic method for representing network devices and protocols (Maj, Murphy and Kohli 2004). According to Maj, this diagrammatic method of interacting with internetworking devices has been clearly demonstrated to enhance learning (Maj, Kohli and Fetherston 2005). The diagrams intrinsically demonstrate concurrent relationships. For example, the diagrams show not only the interface MAC and IP addresses but also the associated Address Resolution Protocol (ARP) table. Students are therefore able to observe relationships, which are the basis of higher order learning in the SOLO taxonomy (Biggs and Collis 1989). Student learning based on SMDs demonstrates a richer conceptual understanding strongly aligned with that of an expert (Maj, Kohli and Fetherston 2005).

Furthermore, as a diagrammatic technique, SMDs are independent of the language of instruction. For example, an SMD-based network curriculum was evaluated in the context of Japanese Professional Graduate Schools. According to Akamatsu, Ohtsuki and Maj (2007),

*"The results strongly suggest that using these methods the students constructed an advanced understanding of network concepts. The results suggest that these diagrams strongly encourage 'deep' multi-structural understanding".*

Meanwhile, learning style in a developing country may be limited to traditional face-to-face classrooms, due to a lack of appropriate technological infrastructure. Students who shift from a traditional learning style to distance education may suffer from a lack of immediate feedback and interaction within a traditional classroom setting (Barnes 2003). Introducing a remote access laboratory for students from developing countries that provides only a limited degree of interaction with a learning environment may result in suboptimal educational experiences. Such a situation might not occur if a higher degree of interaction were possible.

Therefore, the availability of remote access laboratories incorporating the use of SMDs could benefit developing countries. This paper will investigate the suitability of introducing remote access internetworking laboratories in Thailand. In section two, the paper will review the previous literature of implementing such laboratories, particularly those attempted within network technology courses. We will also look at the current situation of network technology education within Thailand. Section three will be used to describe the research process. Section four will demonstrate the findings of the study, followed by a discussion of the results in section five. Conclusions of the study will be provided in section six.

# 2 Previous work

## 2.1 Remote access laboratory in general

The use of remote laboratories in other engineering education disciplines has been well established. According to Machotka, Nedić, Nafalski and Göl (2010), and Nafalski, Nedić, Machotka, Göl, Ferreira and Gustavsson (2010), the use of online remote laboratories can lead to collaboration between universities. Providing a remote laboratory along with a traditional hands-on laboratory was proved to be a valuable solution (Melkonyan, Akopian and Chen 2009). These were all successful examples of integrating remote access laboratory in online or e-learning environments for distance education. Such distance environment can be very important in societies.

In order to provide remote access laboratory successfully, Tomov (2008) has noted two essential elements; action and response. Action will allow users to control laboratory equipment remotely; while response will report the status of the equipment to the users and let them perceive the laboratory practice results. This therefore means that there should be responsive and meaningful feedback from the devices in exercises.

## 2.2 Remote access laboratories in internetworking education

A number of implementations of remote access laboratories have been used in the field of internetworking education. Commercial tools such as Netlab+ can provide access to real networking hardware (Prieto-Blazquez, Arnedo-Moreno and Herrera-Joancomarti 2008). However, the cost effectiveness of commercial tools is still an issue. One alternative to reduce the cost may consider an option to increasing the number of users. According to Jakab et al. (2009) sharing equipment by remote access is routinely conducted by universities.

However, the use of a primitive remote access laboratory may lead to frustration. Yet, comparative studies of remote access laboratories and traditional laboratories were undertaken and the conclusions favoured the use of remote access laboratories (Aravena and Ramos 2009, Lawson and Stackpole 2006). One of the factors may be that distance laboratory can be more suitable for a wider range of students. For instance, an example of providing remote laboratory to vision-impaired students has also been investigated (Murray and Armstrong, 2009).

It may be concluded that the field of remote access laboratory provision has been extensively investigated. This has mainly been focussed upon providing access to a physical laboratory which is an action element according to Tomov (2008). However, most remote access laboratories investigated were based upon text-based interaction with network devices.

## 2.3 Internetworking education in Thailand

Thailand also has a long term focus on building a strong and effective e-learning facility as part of the country's main development plan. Although, Thai universities commenced the development of e-learning in 1994, the

Master planning for educational ICT usage was only commenced in 2004 (Laohajaratsang 2009). This plan was endorsed in the national policy statement delivered by the prime minister in 2008, as a means of supporting further education (Vejjajiva, 2008). The corresponding policy from the Ministry of Education of Thailand also promoted e-learning throughout the education system from primary school to university level (Ministry of Education of Thailand, 2010). The current investment plan for the financial year of 2010 to 2012 also reflects this trend by continuing to support the building of e-learning facilities as well as the development of digital courseware (Ministry of Education of Thailand, 2009). However, this plan appears to have been affected by the global financial crisis. Meanwhile, in the last decade Thailand has experienced a lack of technological facilities to deploy e-learning, such as national broadband internet, limited bandwidth of local network and relatively low numbers of computers throughout the educational system (Sirinaruemitr, 2004).

Furthermore, the take-up of e-learning of within internetworking education in Thailand, compared to that in Australia, can be indicated by considering the statistics of the Cisco Network Academy Program (CNAP) for both of these countries. According to Cisco (2009), if we compare the number of institutes using the CNAP program and the higher education institution list provided by the International Association of Universities (IAU), we find that the majority, around 90%, of Australian institutions are schools or vocational education campuses. Very few are higher level educational institutions. In contrast, only 13% of the institutions using CNAP in Thailand are not tertiary. Australia has embedded e-learning technologies in the school systems to a greater extent than Thailand has yet been able to achieve. More specifically, Australia is using technology to introduce school students to the field of internetworking education at a much earlier age. Thailand is yet to take up this challenge. Several reasons may have contributed to this situation, for example, the availability of networking equipment for schools, computer facilities, the training of teachers and technical personnel. E-learning by electronic media in Thailand is still considered as novel and under development (Lertkulvanich et al. 2008).

However, Thai universities have started to encompass e-learning technologies. Suanpang and Petocz's (2006) study found positive results arose from the provision of e-learning in standard units offered by a university. Significantly improved grades were achieved by students who were enrolled in the online mode of their courses. However, examples of e-learning application to the area of internetworking education are still limited. Therefore, introducing other more affordable forms of providing internetworking education may assist in enabling its take-up at earlier educational levels in Thailand. These considerations led the authors to collaborate with a Thai university to undertake the following research.

# 3 Research

## 3.1 Objective of the study

The objective of this study was to investigate the suitability of introducing remote access laboratories in Thailand by designing and using a multi-media based teaching platform that employs commonly used low-cost technologies to enhance the learning experience of remote students.

## 3.2 Experimental design

The dedicated internetworking laboratory was located in an Australian university. This laboratory had multiple class sets of internetworking devices. An Access server made it possible to provide access for individual remote students in Thailand to specific devices in the Australian laboratory (Figure 1). The server was configured to provide secure access over the Internet. The only technical requirement for the on-line students was a PC and an Internet connection.

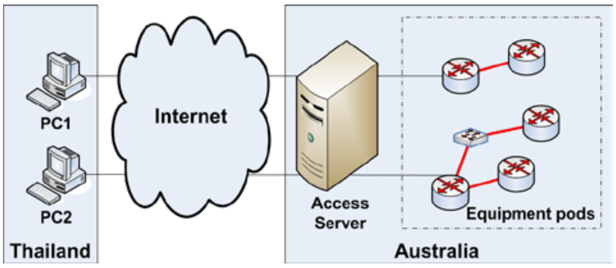



Figure 1: Diagram showing connectivity

As the laboratory operated in a normal mode, the standard method of configuring internetworking devices was the Command Line Interface (CLI). An example of the *show ip route* command is shown in Figure 2.

```
Router3>
Router3>en
Router3#show ip route
Codes: C - connected, S - static, R - RIP, M - mobile, B - BGP
       D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2
       i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
       ia - IS-IS inter area, * - candidate default, U - per-user static route
       o - ODR, P - periodic downloaded static route

Gateway of last resort is not set

     20.0.0.0/24 is subnetted, 1 subnets
C       20.1.1.0 is directly connected, Ethernet1/0
R    200.200.2.0/24 [120/1] via 192.168.2.2, 00:00:22, FastEthernet0/0
C    200.200.3.0/24 is directly connected, Loopback0
R    10.0.0.0/8 [120/1] via 192.168.2.2, 00:00:22, FastEthernet0/0
C    192.168.2.0/24 is directly connected, FastEthernet0/0
Router3#
```

Figure 2: Example of input and output CLI

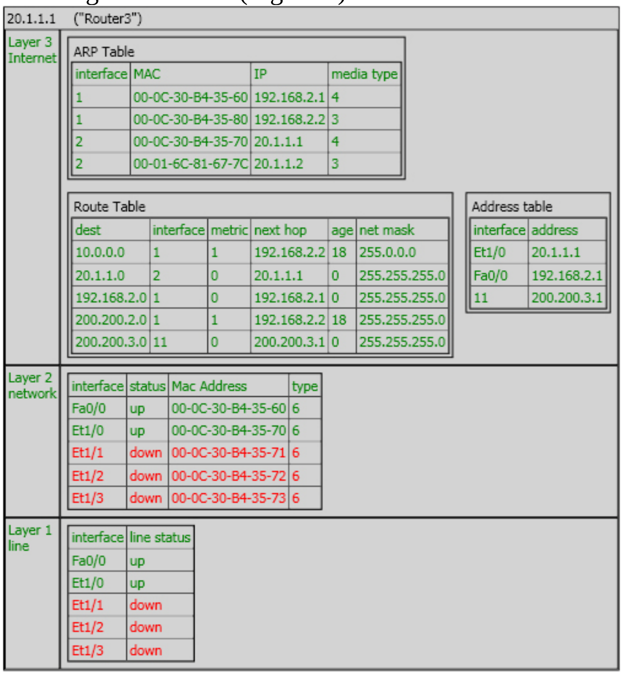
However, the output from multiple CLIs can be captured using a single SMD (Figure 4). This is important because students are able to observe how the different protocols interact.

The SOLO taxonomy category's definitions of learning are: unistructural, multistructural, relational and extended abstract (Biggs and Collis 1989). Relational learning is the integration of several aspects so that the whole has a coherent structure and associated meaning. SMDs are able to provide the basis of relational or higher order learning.

Typically interaction with a physical object is the initial phase of model development that is later modified to a more conceptual construct. It is important therefore for students to actually 'see' the internetworking devices they configured by means of webcam. This is an element which supports the enactive-learning-stage, by letting students learn by the interaction of physical objects (Barnes 2003).

Lecture material was presented in Australia to the Thai students via WebEx which incorporates Voice over IP (VOIP) and integrated Webcam. WebEx is a commonly used, low-cost method for delivering web-based conferences.

The Thai students were therefore provided with an integrated learning platform, all of which was displayed on a single PC screen (Figure 4).




| interface | MAC | IP | media type |
|---|---|---|---|
| 1 | 00-0C-30-B4-35-60 | 192.168.2.1 | 4 |
| 1 | 00-0C-30-B4-35-80 | 192.168.2.2 | 3 |
| 2 | 00-0C-30-B4-35-70 | 20.1.1.1 | 4 |
| 2 | 00-01-6C-81-67-7C | 20.1.1.2 | 3 |

| dest | interface | metric | next hop | age | net mask |
|---|---|---|---|---|---|
| 10.0.0.0 | 1 | 1 | 192.168.2.2 | 18 | 255.0.0.0 |
| 20.1.1.0 | 2 | 0 | 20.1.1.1 | 0 | 255.255.255.0 |
| 192.168.2.0 | 1 | 0 | 192.168.2.1 | 0 | 255.255.255.0 |
| 200.200.2.0 | 1 | 1 | 192.168.2.2 | 18 | 255.255.255.0 |
| 200.200.3.0 | 11 | 0 | 200.200.3.1 | 0 | 255.255.255.0 |

| interface | address |
|---|---|
| Et1/0 | 20.1.1.1 |
| Fa0/0 | 192.168.2.1 |
| 11 | 200.200.3.1 |

| interface | status | Mac Address | type |
|---|---|---|---|
| Fa0/0 | up | 00-0C-30-B4-35-60 | 6 |
| Et1/0 | up | 00-0C-30-B4-35-70 | 6 |
| Et1/1 | down | 00-0C-30-B4-35-71 | 6 |
| Et1/2 | down | 00-0C-30-B4-35-72 | 6 |
| Et1/3 | down | 00-0C-30-B4-35-73 | 6 |

| interface | line status |
|---|---|
| Fa0/0 | up |
| Et1/0 | up |
| Et1/1 | down |
| Et1/2 | down |
| Et1/3 | down |

Figure 3: SMD diagram of router

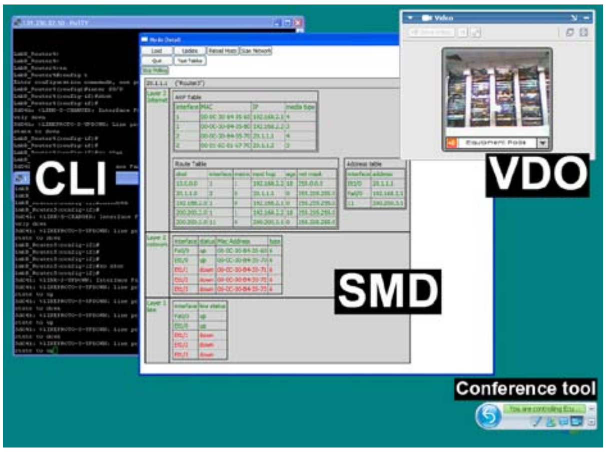



Figure 4: PC's WebEx screen shot showing Webcam, CLI and SMD

### 3.3 Data collection and analysis

The learning platform was evaluated by students, who were enrolling in Cisco Certified Network Associate Program (CCNA). Participants had previous experience in working with Cisco simulation software, Packet Tracer. Therefore, the participants had some familiarity with the equipment and the content of the exercise used in the study.

The participants were asked to sit in the online classroom for two hours in total. The first session was used for an introduction and housekeeping. Then, a lecture about a simple topic in networking technology was given through online web conference software. After the lecture, the participants were able to use the laboratory through the online connection. The remotely located Thai participants were asked to configure network equipment according to the learning material from the lecture. After configuration they were able to see responses from the command line interface (CLI), a video camera and state model diagrams (SMDs). At the end of the session participants were invited to complete a questionnaire asking for their opinion on using SMDs in a remote environment. The questionnaire consisted of closed questions, which are using five point Likert scale (from 1, strongly disagree, to 5, strongly agree). Open ended questions were also available for the participants to write any further details about their opinions.

Due to the distance between researchers and participants, the initial data collection was undertaken via a paper-based questionnaire. The data analysis report was pre-designed before the actual data collection process by using a web-based tool (Qualtrics). This tool could then be reused with a larger number of participants in the future study phases.

### 3.4 Questionnaire

The questionnaire used in this survey is consisted essentially of three parts. The first part contained questions pertaining to the participant experiences of the current facilities provided by their university. The second part contained questions relating to the participants' experiences of using the remote laboratory. Whilst the third part of the questionnaire asked about participants experiences of using the SMD application. Some key questions are presented below.

1. Participants' home university laboratory:
   Q1: Do you have the access you would like to your own university laboratory?
2. Opinions on remote access laboratory:
   Q2: Do you think your university should provide remote access facilities and use it for teaching computer networking?
   Q3: When comparing the remote lab with traditional laboratory access, by which mode would you prefer to be taught?
   Q4: When comparing the remote lab with simulation software, by which mode would you prefer to be taught?
   Q5: When considering the effectiveness of remote instruction compared to an instructor available locally, which mode of instruction you prefer?
   Q6: Do you think you have more freedom by working with a remote instructor without any supervision from a local instructor?
   Q7: Do you need a local instructor to be with you when the remote instructor was available to help during the remote lab time?
3. Experience of using SMD online:
   Q8: What are your preferable combinations of learning tools form the following: CLI, Video stream of real network equipment, SMD application?
   Q9: Do SMDs assist retention of knowledge gained via the laboratory?

Q10: Do you think that SMD is a useful tool for when you learn via remote internetworking environment?

## 3.5 Data sample

There were twelve participants interested in attending the remote teaching and laboratory session. There was a time difference between Thailand and Perth of only one hour. A combined two hour laboratory and lecture session was conducted independently from the participants' original coursework. However, only seven participants had completed the questionnaire by the time this paper was written and there was only limited number of responses. These preliminary investigations were undertaken to discover possible issues prior to the commencement of a larger scale study.

# 4 Results

The results from Q1 shows 43% of respondents do not feel satisfied with their current level of access to laboratory network equipment. The main reason was that students are allowed to use the equipment only in the scheduled class time.

Consequently, 71% of respondents felt that their institutions should provide further access via a remote access facility (Q2). The volunteers indicated remote access was a preferable method of self practice when compared to the traditional face-to-face laboratory (Q3), by 85% comparing with 15%. When comparing student attitudes to remote access laboratories and simulation software (Q4), 42% percent of the respondents preferred a remote access laboratory, while increasingly 28% still preferred the use of simulation software.

Furthermore, results from Q5 shows 42% percent of respondents agreed that they prefer to have the same instructor available locally when they are using a remote laboratory. Correspondingly, 56% did not enjoy the freedom of practicing in a remote laboratory without supervision from local instructors (Q6). One of the comments from the respondents is as stated below:

*"We need a local instructor to stay with us, as the remote instructor may not be able to rectify any usage problem on time."*

More than 85% of the respondents feel that it is necessary to have a local instructor with them during the laboratory time, even though the remote instructor was present (Q7).

When asked the participants to give a score (from 1 – 5 of Likert five point scale) to the preferred combination of learning components that should be available on the remote access network laboratory (Q8), the majority would like SMDs, video webcam and CLI to be available. Table 1 shows the mean score and standard deviation of each choice. A choice which contained only CLI has the lowest mean score amongst all combinations. Most of the participants would not like to have only CLI available on the remote access laboratory, even though they are already familiar with Cisco's device commands. However, within the lower range of score deviation (0.76 - 0.79), the combination of providing CLI and video webcam showing real-time equipment has the highest mean.

| Appreciation score | Mean | SD |
|---|---|---|
| CLI only | 2.71 | 0.76 |
| CLI and Webcam | 3.57 | 0.79 |
| CLI and SMD | 3.43 | 0.79 |
| CLI, SMD and Webcam | 4 | 1.15 |

Table 1: Preferable learning components

When asked about the pedagogical value of SMD (Q9), 71% of the respondents agreed that SMDs help them retain the knowledge from the laboratory exercise. This confirmed the benefit of SMD to the students according to Akamatsu et al. (2007). Particularly, a similar proportion of the respondents agreed that SMDs helped them during their learning process in the remote access laboratory (Q10).

The data gained from this preliminary study may indicate benefits of using a remote access laboratory and clarify the preferred learning style of Thai students. The result may also identify student perceptions of the presented remote laboratories when compared with traditional and simulation laboratories.

# 5 Discussion

## 5.1 Discussion and future work

The results may indicate a high demand from Thai network students for laboratory facilities to be used for practice using internetworking devices. They also indicate the necessity of providing other means of practising for students. Further results from Q5-Q7 show that Thai students may lack experience of working with a remote access laboratories and learning in an e-learning environment. Students tend to prefer to study in a traditional style by using real equipment available on site with a local instructor. Such traditional mode of delivery is what Thai universities currently attempt to provide. Furthermore, Thai learning styles may rely more on the presence of local teachers and indicate the extra responsibility placed upon remote lecturers. Interestingly, this extra need may be shown by the participant's comment below:

*"The remote instructors may have some difficulty to control the local student to pay attention to the class."*

However, when it comes to offering practice time for laboratory exercises, the participants also realize the value of practicing by using the remote access laboratory. The laboratory's availability outside the scheduled class times can offer more flexible access to the students.

When asked to compare the simulation laboratory with the remote access laboratory, although the majority, 42% of participants still favoured the remote laboratory, some participants indicated that they would still prefer to use simulation software. This may be because the simulation software can offer more flexibility of access, even surpassing the remote access laboratories. Furthermore, the students have been exposed to the simulation software for a long period and may be used to it. Also, the lack of accuracy of the simulation tools may not be a concern from the student perspective at this stage. This can be illustrated by the following participant's feedback: *"Using simulation software is similar to using real equipment in every detail."* However, the majority still prefers the remote access laboratory.

When using the provided remote access equipment, students may not realize that they are actually working on real equipment. A comment to illustrate this point is: *"I prefer to use real equipment rather than remote access laboratory"*. This also pointed out the need of providing more responsive media to the laboratory's interface in order to make the students feel the situation was more realistic.

When considering the part of result from Table 1 that has only the lower range of deviation, the participants were interested to have the combination of CLI and video webcam showing the equipment when they were doing exercises. This may be because they were seeking a similar working environment to the face-to-face laboratory, where they can see the actual equipment. The same result can also indicate that the participants may not be familiar with the SMD software used in this study, as the software was introduced as a new teaching medium. This could suggest the future work to employ an extension of learning session for building tools familiarity.

The differences between the mean scores in Table 1 provide an indication that CLI alone in the remote access laboratory was not an effective solution. This could support the consideration of symbolical CLIs lower pedagogical value. Integrating other means of teaching media such as SMDs may benefit the student learning process. This has demonstrated the need for multimedia pedagogy-rich learning environments for remote students, who may lack the encouragement often provided in an actual laboratory.

Therefore, the internetworking distance learning situation of Thailand still needs more improvement. Especially, educational institutions need to correct students' perceptions as a necessary requirement for studying online courses (Gulatee and Combes 2008). Research shows that Thai students' learning styles differ from those of Western students; they appreciate group learning (Selvarajah, Chelliah, Meyer, Pio and Anurit 2010). One of the main problems of Thai students may relate to cultural factors. They may lack both the ability to learn independently and critical thinking skills and tend, therefore, to rely more on local lecturers. This obstacle may have a larger effect on their online learning, as online learning needs more self discipline and independence. Precautions may be needed when instructors are trying to implement a remote access laboratory in a fully unsupervised learning model with Thai students.

Moreover, lectures and the demonstration of the laboratory exercises may need to be delivered by traditional modes to suit student requirements; the independent practice session may be conducted by means of the remote access laboratory. However, the development and application of such a facility should also consider the different cultural requirements and learning styles.

## 5.2 Problems and lesson learn

When remote laboratory were provided to distant students in this study we faced a variety of issues.

Firstly, the usage of traditional remote access methods that provide only the one-way CLI configuration screen to the distant students may not suitable for class demonstration. This was especially when students need an instant response from remote instructor of their immediate configuration.

Secondly, communication was always an issue in our case. We had some disconnection problems and realized that we should have other standby networks as backup.

Lastly, time availability was also another problem as our laboratory is quite packed during the semester time. Fortunately, Thai universities operate within a different period of the year and we could use this gap to better utilise the equipment.

# 6 Conclusion

This paper is an initial investigation in order to investigate the technical issues with providing concurrent access to multiple remote students.

This study found that network technology students in Thailand face the problem of lack of practice equipment and look for other means of support, either from a remote access laboratory or simulation tools. This study also raises the concern on implementing a fully distance learning environment for network technology classes in Thailand as it may introducing different challenges. Especially, the challenges may relate to support and guidance within the learning environment. For example, 85% of the respondents requested extra guidance from a local instructor even though the remote instructor was present. Also, the study was concerned with the value of traditional remote access configuration methods (CLI) when using with network technology classes. CLI, on one hand, is not a fully appreciated teaching tool from student perceptions by having the lowest appreciation score amongst all four alternatives of 2.71 from 5 point scale; even though the respondents in this study are familiar with CLI and have already attained a level of professionalism. Remote access laboratories may well need to provide more than text-based CLI access. Pedagogically-rich, multimedia learning environments, which offer multiple learning materials to suit different learning styles, should be considered and incorporated into remote access laboratories for networking education. SMDs and webcams, on the other hand, have been introduced in this study to help compensate for the difficulties of a remote learning environment. This study shows that the integration of both tools in the remote access laboratory will benefit distance learners. For example, 70% of the respondents agreed that SMD is necessary for them in remote access environment.

Therefore the remote access laboratory could be of benefit to computer networking education in Thailand as a whole. Although simulation software has the advantages of portability and accessibility, issues of accuracy still remain. The remote access laboratory, on the other hand, may offer a better degree of availability than the traditional laboratory; however, students may need time to adapt to the new teaching environment.

Educational providers, especially in developing countries, may need to understand current student perceptions of online facility usage and focus on building other skills necessary for the students to study independently. Further research into these areas is recommended by the authors.

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