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AN INVESTIGATION INTO INTERNETWORKING EDUCATION

By

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MS., Computer Science**

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**This thesis is presented in fulfilment of the requirements for the degree of
Doctor of Information Technology**

**Faculty of Computing, Health and Science
Edith Cowan University**

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USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

ABSTRACT

Computer network technology and the Internet grew rapidly in recent years. Their growth created a large demand from industry for the development of IT and internetworking professionals. These professionals need to be equipped with both technical hands-on skills and non-technical or soft skills. In order to supply new professionals to the industry, educational institutions need to address these skills training in their curricula.

Technical hands-on skills in internetworking education can be emphasised through the practical use of equipment in classrooms. The provision of the networking equipment to the internetworking students is a challenge. Particularly, university students in developing countries may find that this equipment is ineffectively provided by their teaching institutions, because of the expense. Modern online learning tools, such as remote access laboratories, may be used to address this need. However, the provision of such tools will also need to concentrate upon the pedagogical values. In addition, traditional remote access laboratories provide only text-based access, which was originally designed for highly professional use. Novice students may struggle with learning in these virtual environments, especially when the physical equipment is not available locally.

Furthermore, non-technical skills or soft skills are social skills that should not be neglected in graduates' future workplaces. A traditional model of developing soft skills that was used in face-to-face classroom may not be as effective when applied in an online classroom. Research on students' opinions about their soft skills development during attending internetworking courses is needed to be conducted.

In order to address both research needs, this study was focused on two research aspects related to online learning in internetworking education. The first focus was on research into providing a suitable technical learning environment to distance internetworking students. The second focus was on the students' opinions about their non-technical skills development.

To provide a close equivalent of a face-to-face internetworking learning environment to remote students in Thailand, a transformation of a local internetworking laboratory was

conducted. A new multimedia online learning environment integrated pedagogically-rich tools such as state model diagrams (SMDs), a real-time video streaming of equipment and a voice communication tool.

Mixed research data were gathered from remote online and local student participants. The remote online participants were invited to use the new learning environment developed in this study. Qualitative research data were collected from twelve remote online students after their trial usage. Concurrently, another set of research data were collected from local students asking their opinion about the development of soft skills in the internetworking course. There were sixty six participants in this second set of research data.

Although the research data was limited, restricting the researcher's ability to generalise, it can be concluded that the provision of multimedia tools in an online internetworking learning environment was beneficial to distant students. The superiority of the traditional physical internetworking laboratory cannot be overlooked; however, the remote laboratory could be used as a supplementary self-practice tool. A concrete learning element such as a real-time video stream and diagrams simplified students learning processes in the virtual environment. Faster communication with the remote instructors and the equipment are also critical factors for a remote access network to be successful. However, unlike the face-to-face laboratory, the future challenge of the online laboratory will creating materials which will encourage students to build soft skills in their laboratory sessions.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

- (i) incorporate without acknowledgment any material previously submitted for a degree or diploma in any institution of higher education.
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CHAPTER 1 INTRODUCTION

1.1 Introduction

Computer networks have expanded rapidly. Today, this expansion is not limited to large corporate computer networks but it is also related to personal computer networks connecting via larger public networks such as the Internet.

Internetworking or inter-networking was defined as the practice of connecting a computer network with other computer networks (Cisco, 2011a). In other words, inter-networking is a practice involving inter-relationship between computer networks. The Internet is one well known example of large-scale internetworking. As a consequence, inter-networking education is a study involving both theories and practices of connectivity between networks. This involves routing protocols, and the function of internetworking equipment such as routers and switches. Basically, these fundamental internetworking devices are given the following definitions (Dye, McDonald, & Rufi, 2008):

- Switch: *“A layer 2 devices that receives an electrical signal in one port, interprets the bits, and makes a filtering or forwarding decision about the frame....Switches are different from hubs by their ability to reduce the congestion domain (Dye, et al., 2008, p. 349)*
- Router: *“A network device, typically connected to a range of LAN and WAN interfaces, that forwards packets based on their destination IP addresses...Router helps direct messages between networks (Dye, et al., 2008, p. 13)*
- Routing protocol: *“A protocol used between routers so that they can learn routes to add to their routing tables...They are the set of rules by which routers dynamically share their routing information. As routers become aware of changes to the networks for which they act as the gateway, or changes to links between other routers, the information is passed on to other routers. (Dye, et al., 2008, p. 164)”*

Inter-networking education is by necessity concerned with the inter-connection of such a large-scale network as the Internet. Hence internetworking education includes not only theoretical aspects of computer networks but also commercially practical aspects.

Since the introduction of the Internet, corporate networks and other personal networks have emerged. This has led to an even greater expansion in networking. The required numbers of networking engineers to support this rate of network growth is a challenge for many educational institutions. Within universities themselves, there has been a variety of approaches from both computer science and telecommunications engineering perspectives with increasing numbers of students enrolling with a variety of skills and understanding.

Moreover, other commercial institutions such as network equipment vendors have also become significantly involved in many educational processes. Commercial vendors-driven curricula have offered another approach which is now integrated into many universities' curricula. This is as Veal, Kohli and Maj (2005, p. 2) had stated that: "the fast moving of technology is a factor favouring the integration of vendor certification programmes within universities particularly in the area of computer networking". There are many benefits of this approach, especially a focus on the objective of graduates' eventual employment; Schlichting and Mason (2004, p. 161) stated that "*industry seems to agree that certification makes graduates more employable*". However, there are some disadvantages (Maj & Veal, 2007), which may need to be addressed. The involvement of multiple course providers with different aims is one of the factors complicating networking education issues.

Particularly, integration of vendor-driven curricula into university internetworking education courses may infer ethical issues. As Veal et al. (2005, p. 4) stated "A question sometimes raised is that of the ethics of running units from a single commercial provider". Sometimes, the integration may lead universities to question the suitability of the curricula offered. For example, the vendor-based internetworking curricula offered from Cisco, the Cisco Network Academy Program (CNAP): the Cisco Certified Network Associate (CCNA) and the Cisco Certified Network Professional (CCNP), may be constructed from different learning objectives than that of the universities. Maj and Veal stated that: "*an extensive analysis of the CNAP curriculum found that the main emphasis was on remembering rather than learning*" (Maj & Veal, 2007, p. 1). Moreover, "the CCNA and CCNP are based primarily on the Command Line Interface

(CLI)” (Maj & Veal, 2007, p. 1). The CLI is a text-based command for configuring networking devices to carry out desired functions. An excessive emphasis on CLI may cause learning difficulties for novice students (Maj, Kohli, & Fetherston, 2005, p. 1). Therefore, applying straightforward vendor-driven curricula without taking any other factors into consideration may lead to negative results in the longer term.

In terms of course delivery methods, there are various approaches that may be more suitable under different circumstances. In order for educational institutions to achieve improved learning outcomes in networking education, the provision of laboratory exercises is a major critical factor (H. Hong & Shengzhong, 2009). There are at least three different ways to provide laboratory exercises in the networking education field. These are (1) local hands-on laboratories, (2) simulated laboratories and (3) remote access laboratories (Ma & Nickerson, 2006). Each delivery method may be more suitable for different students and circumstances. For example, a local hands-on laboratory offers a full, rich, first-hand experience for students, but requires physical access to equipment. In contrast, a simulated laboratory may be provided by simulation software, such as Packet Tracer and OPNET. This simulation software is currently integrated to vendor-driven curricula and offers a low cost virtual experience without physical interaction with real equipment. A remote access laboratory (RAL), on the other hand, offers a near-realistic experience by providing the real equipment from a distance, but has its own issues. There are still debates about the comparisons between these three delivery methods and many aspects still require further development (Ma & Nickerson, 2006; Sivakumar & Robertson, 2004).

Cost is another factor that schools of computer science within universities need to consider when embracing any laboratory delivery method in their courses. In order to equip the laboratory fully with suitable hardware, universities face many difficulties and one of them is funding (Yoo & Hovis, 2004, p. 1). For instance, the CCNA and CCNP laboratory may cost over AUS\$300,000 (Veal, et al., 2005, p. 3). Educational institutions already face funding problems and seek ways to reduce their costs. This is as Ma and Nickerson (2006) stated “Universities are struggling with the heavy financial burden of maintaining expensive apparatus in traditional laboratories and seek to maintain the effectiveness of laboratory education, while at the same time reducing the cost”. Therefore, finding an economically viable teaching solution is important for networking educators.

Virtual learning environments (VLE), as a broader form of online learning environments, is one example of economical teaching approaches which embrace more than one delivery method. This virtual environment creates a learning facility designed to support teachers in the management of educational courses for students, especially a system using computer hardware and software, which involves distance learning. The tools for achieving this may sometimes be called a learning management system (LMS) (Stiubiener et al., 2006, p. 4). According to Perrie (2003), there were many advantages when applying virtual learning environments within universities' curricula. For example, VLE material can take a variety of forms e.g., text, graphics, audio, and video. VLE can be delivered at any time to almost any IT accessible place. Problem-based learning is one area of VLE that can be easily incorporated and automated responsive feedback provided (Perrie, 2003). In this context, problem-based learning means a teaching approach that promotes the opportunity for students to get involved in realistic situations within a facilitated environment. This contrasts with traditional curriculum approaches which focus on teaching topic by topic without any concern for realistic problems (Merrill, 2007). However, some disadvantages of VLE are: increased learning expectations need the systems to be more sophisticated and complex which requires more tutor administration; both tutors and students may need extra training on the administration and running of the VLE; off campus access can be slow and expensive (Perrie, 2003). Because of these disadvantages, further improvements are required if VLEs are to be used for internetworking units.

The Cisco Network Academy Program (CNAP) is an example of an extensive program for networking education with an integral e-learning component. The CNAP encompasses VLE principles by its web-based learning environment. It emphasises the need for a hands-on laboratory but also uses network simulation software. However, it has a major drawback as mentioned earlier, namely that: "Significantly the CNAP curriculum tends towards a "black box" approach, that is contrary to constructivism, a major educational theory today that has been extensively tested in the fields of science and mathematics education" (Maj & Veal, 2007, p. 1). Students are encouraged to construct knowledge through building their own conceptual models. However, without suitable guidelines, their models could be inaccurate. This problem can be solved by providing students with an abstract model as a basic framework to assist the learning process.

Meanwhile, a wide range of models has been used in networking education and each has been found to have its own advantages and drawbacks. The advantages of using models within networking education are that they are diagrammatic, easy to use, they also provide the ability to control detail and integrate the information from different networking components (Maj, Murphy, & Kohli, 2004, p. 2). There are various modelling techniques included: object-oriented modelling, function-oriented modelling such as data flow diagrams (DFDs) and structured analysis and design. However, it has been noted that: “most of these methods could capture information flow, and device behaviour but it was difficult to relate the model results to the data extracted from the CLI” (Maj, et al., 2004, p. 2). The CLI is the command line interface used extensively by professions in the field; however, this was not designed for the needs of students. Since CNAP offerings have been based primarily on CLI (Maj & Veal, 2007, p. 1), the usage of these CLI-based modelling techniques may not be suitable. Therefore, finding a more suitable modelling technique for capturing the related data from networking devices is of importance within the field of internetworking education.

1.2 The Background to the Study

State Model Diagrams (SMDs) have been proposed by Maj et al. (2004) as tools which provide hierarchical levels of information, a conceptual model and a visual aid. State models provide abstraction and information hiding to aid students’ understanding (Kohli, Maj, Murphy, & Veal, 2004, 2005). They have been used and evaluated in conjunction with vendor-based curricula. Results from previous studies (Maj, et al., 2005; Maj & Veal, 2007) showed the positive side of using SMDs integrated with the teaching process and in hands-on laboratories.

However, the evaluations before 2007, had only been carried out on manual paper-based diagrams (Maj & Veal, 2007, p. 205). In order to suit distance learning environments, SMDs may need to be adjusted as a form of software which may be integrated easily within simulations or remote access media. This indicates a further need for development. Building this software was another research and development that is currently in progress (Maj, Makasiranondh, & Veal, 2010). Obviously, the development of SMD software may be improved by being implemented independently from vendor-specific equipment or protocols (Maj, et al., 2004, p. 14). Also, there is a need for further evaluation of the new form of SMD against its applications in distance learning environments.

1.3 The Significance of the Study

This research investigated State Model Diagrams (SMDs) as an additional tool as part of the pedagogically rich online learning environment in a computer internetworking curriculum. Most computer networks are built to accommodate the needs of any business organisation, academic institute or working group. Hence, internetworking is a well-known technology that assigns multiple, diverse, underlying hardware by providing the heterogeneous networks.

Relatively few academic institution and universities have dedicated networks for students use for experimentation. However, strict requirements limit students and general users accessing the functional networks and laboratory equipment. Hence, the online learning environment, with SMDs as the visual models, may assist in compensating for any limitations in the remote accessing laboratory of internetworking. By integrating the SMDs into the internetworking curriculum, students may obtain a more complete picture of the network and have a better understanding of the physical as well as the logical network topologies.

Using the SMDs integrated with normal university curricula may help students gain a better understanding of the course contents and to satisfy the course objectives. This study attempts to determine whether the proposed method of using a remote classroom as a distance learning tool is sustainable and suitable for remote students who have limited hands-on resources. With the help of SMDs, it could also expand the possibility of effective distance learning in the field of internetworking education. It may also assist many educational institutions in their decisions to incorporate online hands-on learning into their existing facilities to maximise the benefits for students in learning and self development.

1.4 The purposes of the study

The first purpose of this study is to investigate the effectiveness of the State Model Diagrams (SMDs) in remote teaching approaches of network technology education. It will focus on a remote access classroom as a delivery method that creates a significant improvement in network technology education. In order to integrate SMDs into remote environment, where the communication between lecturer and student is limited; the SMDs in the form of software need to be developed and used as an interaction tools with the students. Overall, this research will investigate the following areas:

- Improvement of the SMDs by implementing it to be used with remote environment and also independently from any specific vendor equipment or proprietary protocols.
- Evaluate the effectiveness of the SMDs software when using it in a standard university classroom.
- Evaluate the effectiveness of SMDs software when using it with a remote access classroom.
- Compare and evaluate the effectiveness of remote access classroom as a network education tool with vendor-driven curricula.

Maj and Veal (2000) had noted that advanced computer technology is now managed as a modular system which demands skills often not provided by the traditional computer science curriculum. The result from the same survey (Maj & Veal, 2000) revealed that students want to have better knowledge and understanding of computer technology, but they failed to see the relevance of the current curriculum. Also, the problems of the teaching computer technology are not a new phenomenon. The use of software simulation, diagram or model has proved to be a very useful tool (Reid, 1992).

In order to improve students' understanding, a conceptual model of an internetworking device should allow the student to assimilate concepts. The SMDs for internetworking curriculum may be suitable for different levels of complexity by this means supporting not only introductory at the fundamental of computer networking but also more superior in practical concepts.

The purpose of this research was to evaluate the preliminary remote learning environment which incorporated the SMDs as a pedagogical tool. It was done by examining the results of using the SMDs in internetworking courses and the implication of computer networking curriculum upon vendor-based. The investigation results may improve the learning outcome for IT students who interested to be a professional network engineer or a network specialist. This work also offers a great opportunity to overcome the difficulties in computer networking contents.

The second focus of this study was to investigate the internetworking students' opinions on development of soft skills in their internetworking course, online and offline. Graduates of internetworking course were not only need their technical skills to be fully

developed but are also required to be equipped with soft skills or non-technical skills (Bleek, Lilienthal, & Schmolitzky, 2005, p. 8; Tucker, 1991, p. 72). This concern has also been raised in a number of model curricula (Association for Computing Machinery [ACM] & Association for Information Systems [ACS], 2010; ACM & IEEE Computer Society [IEEE-CS], 2008a; Tucker, 1991; Yuan & Zhong, 2010). The development of such skills needed to be emphasised in the universities' curricula. However, the regarding perceptions of students of those skills were also need to be studied. Especially when conducting internetworking courses online, the teaching of soft skills may need to be different than in face-to-face mode. Further research in this area is needed.

In general, soft skills or non-technical skills could be defined as the skills that human used to interact with other human, specifically when involving with professional works (Tannahill, 2007, p. 1). However, the definition of these skills was not clearly given amongst educators and they were overly defined by other words that can be used interchangeably, which led to the issues of the studies in this area (Daniels, Cajander, McDermott, & von Kinsky, 2011, p. 145).

Therefore another thrust of this research was to investigate on internetworking students' opinions of their development of soft skills, apart from their technical skills. The emphasis of integrating soft skills into internetworking curricula was far more significant, both from academic (ACM & IEEE-CS, 2008a; Tucker, 1991) and IT industry standpoints (Bleek, et al., 2005). However, the integration of such skills into the modern teaching environment such as distance learning has been lightly explored or investigated. The study of students' opinions of their development of soft skills will assist the future adjustment or integration of the future training of such skills in modern internetworking education.

Overall diagram explaining the purposes of this study is provided in Figure 1.

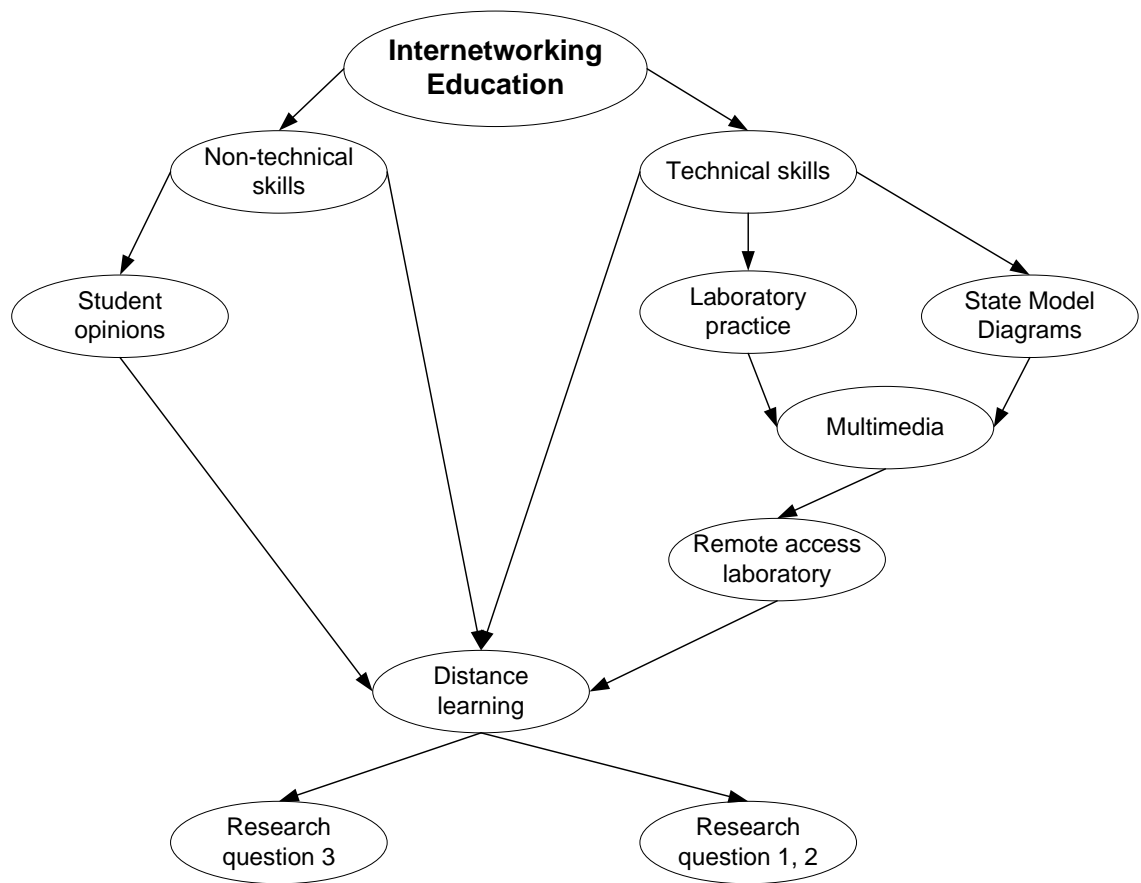


Figure 1. Purposes of the study

The next section describes the research questions of this study.

1.5 Research Questions

1. How can the SMD be used as a pedagogical tool in internetworking education?
 - What is the current position of the SMD in internetwork education, in both development aspects and integration aspects to the network education curricula?
 - Can the SMD help distance learning of internetworking education?
 - How may the SMD be integrated within a distance learning tool such as the remote classroom?
2. How can the remote access classroom help internetworking education?
 - What are advantages and disadvantages of the remote access classroom for students?
 - What is the position of remote access classroom compared with other internetwork teaching approaches?
 - What are the benefits that can be gained from the traditional or instruction-based classroom?
 - What are the factors of the remote classroom teaching needed in order to succeed?
3. What are students' opinions on their development of soft skills in internetworking education?
 - What are students' perceptions of the current training emphasis on soft skills?
 - What are their opinions of training soft skills via online modes?
 - What are skills that students believe or feel confident about?
 - What are the skills that students believe they already have or are confident about?

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

In this thesis, internetworking education involves a number of sub-topics. This chapter covers the overall topic relevant to this research study, starting from the recommendation from model curricula, and the comparison between traditional and modern vendor-influenced curricula. The study of model curricula has yielded a list of recommendations that has structured this research's purposes. The author would like to focus this study to be particular to a developing country like Thailand.

A brief background to general education theory and a discussion about pedagogical tools used in the teaching of internetworking will also be discussed. These tools included the text-based command line interface (CLI), the graphical user interface (GUI) and the state model diagrams (SMDs). Finally, as the demand for online course delivery may have started around the 1990s (Pullen & Chen, 2008), the chapter will also cover the discussion of various delivery mode of internetworking's coursework and laboratories. In general, the overall picture of relevant topics is shown by Figure 2.

2.2 Model curricula

Internetworking education is a part of computer education in which a number of model curricula have been issued by the major computer professional organisations, such as the joint task force between the Association for Computing Machinery (ACM), the Association for Information Systems (AIS) and the Institute of Electrical and Electronics Engineers - Computer Society (IEEE-CS) (see ACM & AIS, 2010; ACM & IEEE-CS, 2008a; ACM & IEEE-CS, 2008b; IEEE-CS & ACM, 2001; IEEE-CS & ACM, 2004; Tucker, 1991); the Australian Computer Society (ACS, 2008); and the British Computer Society (BCS, 2010; BCS, n.d.). These organisations included both representatives and academics in the field of IT industries and IT education and represented the professional demands for skills both of a theoretical and practical nature. Although it was the academic institutions' sole right to decide how to implement their courses, these recommendations were viewed as preferable benchmarks. Furthermore, universities' courses were likely to be controlled or directed by government or other standardised professional accreditation committees.

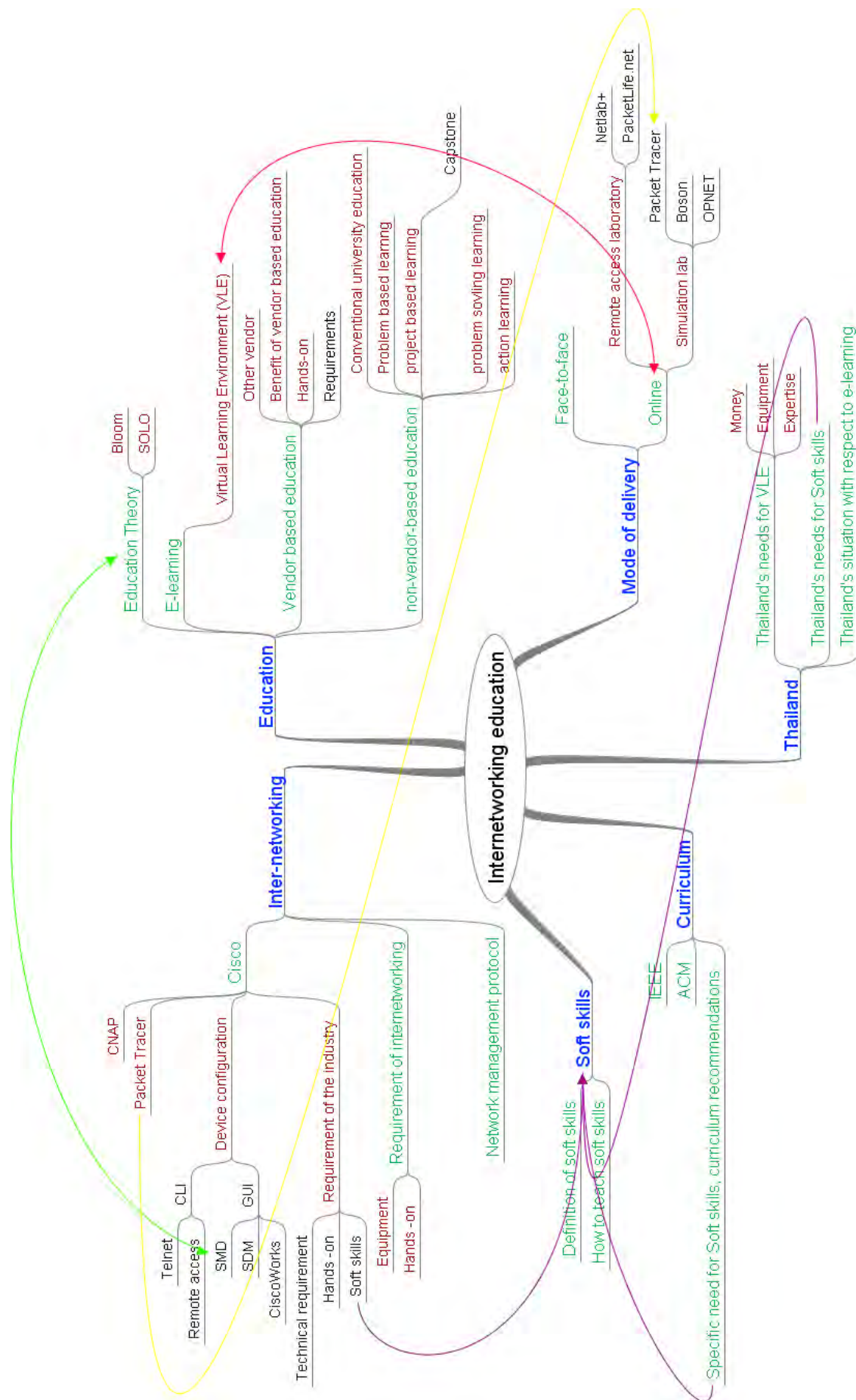


Figure 2. Overall picture of the related literature

In the United States, the accreditation was undertaken voluntarily by non-government committees, such as the Accreditation Board for Engineering and Technology (ABET). ABET (2010) began in 1936 as the Engineers' Council for Professional Development (ECPD) and renamed in 1980. It is a well-known accrediting institute for applied science, computer and engineering programs. IEEE was one of the founder members of the accreditation board. This ensured that their accrediting procedures reflected the needs of the industry and were influenced through professional organisations.

Similarly, Australian universities were required to have a plan for quality assurance; this initiative was started from 1998 (Higher Education Division, 2000, p.8). The overall accreditation framework was referred as the Australian Qualifications Framework (AQF) and was governed by the Department of Education, Employment and Workplace Relations (DEEWR). Other key organisations which were also involved with these accreditation processes were the Australian Universities Quality Agency (AUQA) and other local accreditation committees in each state. From July 2011 AUQA was replaced by the Tertiary Education Quality and Standards Agency (TEQSA) (2011). TEQSA will not begin its regulatory functions until January 2012. However, the former AUQA's main responsibility was auditing and promoting the quality of education at the tertiary level throughout Australia. The Australian Computer Society (ACS) is represented as the computing professional institution in Australia similarly to the US. Hence, Australian universities were engaging with a similar process to the US, but their accreditation process is compulsory.

Similarly in the Thai education system, tertiary courses need to be accredited by the government department called the Office of the Higher Education Commission (OHEC) (Office of the Higher Education Commission, n.d.). Typically, Thai universities followed the ACM/IEEE recommendations (Chookittikul, Kourik, & Maher, 2011, p. 240). Thai universities are able to adopt an autonomous quality assurance system to suit each individual context; however, standardised reports are required to be submitted to OHEC (Bureau of International Cooperation Strategy, 2010, p.16).

Frequently, the recommendations or model curricula of the professional institutions were a major focus of the universities' course structures. Following these recommendations was considered to be highly relevant to quality. According to Yuan and Zhong (2010) the current ACM/IEEE recommendation were fully aligned to ABET

requirements. Therefore, model curricula have played important roles in internetworking education and represented demands from both industry and academia.

2.2.1 Recommendation from the model curricula

2.2.1.1 The increasing significance of internetworking in model curricula

The significance of the model curricula to computer education is undeniable. One of the models was the curriculum recommended from the joint task force of two professional institutes, IEEE and ACM. Before the 1980s ACM and IEEE had their own model recommendations which started to influence the shape of computer science and engineering education, by merging the gap between software and hardware (IEEE-CS & ACM, 2001, p. 41).

After the 1980s, the IEEE and ACM were combined as a joint task force and published recommendations called the *Computing Curricula 1991* (Tucker, 1991). These recommendations have been regularly updated; for example there followed a major revision in 2001 (ACM & IEEE-CS, 2008a; IEEE-CS & ACM, 2001) and the next revision is planned to be available in 2013. Each revision of the recommendations reflected the trend of both technology and also considerations in teaching topics, including internetworking. The traditional development cycle was to update these recommendations within every ten years. However, the demand for a shorter revision period was increased and was interpreted as to be every five years (ACM & IEEE-CS, 2008a, p. 10). For example, the update of the 2001 revision was published in 2008 as an interim version, only seven years from the original publication date.

Originally, Tucker (1991) stated that the joint task force divided the computing curriculum into nine subject areas, which were:

1. Algorithms and Data structures
2. Architecture
3. Artificial Intelligence and Robotics
4. Database and Information Retrieval
5. Human-Computer Communication

6. Numerical and Symbolic Computation
7. Operating Systems
8. Programming Languages
9. Software Methodology and Engineering

At that time, internetworking was considered as a comparatively smaller component in Operating systems area. Later, the much larger trend of internetworking was started to be refined. Internetworking was presented in the later recommendation, 2001, as an emphasised topic.

The lack of emphasis on networking is not particularly surprising. After all, networking was not yet a mass-market phenomenon, and the World Wide Web was little more than an idea in the minds of its creators. Today, networking and the web have become the underpinning for much of our economy. They have become critical foundations of computer science, and it is impossible to imagine that undergraduate programs would not devote significantly more time to this topic. At the same time, the existence of the web has changed the nature of the educational process itself. Modern networking technology enhances everyone's ability to communicate and gives people throughout the world unprecedented access to information. In most academic programs today—not only in computer science but in other fields as well— networking technology has become an essential pedagogical tool (IEEE-CS & ACM, 2001, p. 9).

The current 2008 recommended curriculum refers to internetworking as part of Net-Centric computing, one of the core study areas of computing education. Students might learn the operation of networks, protocols, and the layers of the communication model in internetworking topics. According to the ACM and the IEEE-CS (2008a), internetworking minimally required as much as 7 teaching hours from the 15 recommended hours half of the Net-Centric area in total.

Similarly, another joint task force between the ACM and the Association for Information Systems (AIS) also included internetworking topics in their core courses of the new 2010 recommendations (ACM & AIS, 2010, p. 46). The British Computer Society (BCS) also regarded computer networking or internetworking as important topics (BCS, n.d.). Therefore, internetworking may be considered as a core topic which should be taught to most computing students.

2.2.1.2 Recommendations about hands-on emphasis on model curricula

Moreover, these model recommendations were not just concerned with course contents but also concerned about the methods of teaching and learning the contents. Their focus also paid attention to the direct hands-on experience of the students. According to Yuan and Zhong (2010, p. 257), “*Students are expected to master both theory and hands-on skills in networking technology to be successful in the career.*” The BCS (n.d.) also stated that the objective of learning about computer networks in its syllabus was about integrating both theoretical and practical aspects. The 2001 model curricula stated:

To develop a firm understanding of the scientific method, students must have direct *hands-on experience* with hypothesis formulation, experimental design, hypothesis testing, and data analysis. While a curriculum may provide this experience in various ways, it is vital that students must “do science”—not just “read about science.” (IEEE Computer Society & Association for Computing Machinery, 2001, p. 41)

Again in the 2008 model, it stated:

Mastery of this [Net-Centric] subject area involves both theory and practice. Learning experiences that involve *hands-on* experimentation and analysis are strongly recommended as they reinforce student understanding of concepts and their application to real-world problems (Association for Computing Machinery & IEEE Computer Society, 2008a, p. 60).

Eventually in the 2010 model, it stated:

Whenever possible, it is recommended that this course uses *hands-on laboratory work and practical exercises* to teach the complex concepts that are often too abstract to grasp without practical examples (Association for Computing Machinery & Association for Information Systems, 2010, p. 47).

It is clear that the computing disciplines need to embrace both lectures and laboratory experiences (Tucker, 1991, p. 77). The recommendations from the major model internetworking curricula made it clear that students need to learn by doing, not just by reading and studying the theory in lecture classes. Laboratory exercises became an important factor for internetworking students. It concluded that it was vital to provide significant laboratory access for them to develop their skills.

2.2.1.3 The importance of non-technical or soft skills

Another aspect that these model curricula have recommended was an emphasis on non-technical skills, or soft or professional skills. Concurrently, they suggested including such non-technical skills as the mandatory graduate attributes. “*Undergraduate*

programs should prepare graduates to understand the field of computing both as an academic discipline and as a profession within the context of a larger society (Tucker, 1991, p. 72).” According to the definition given by Tannahill (2007, p. 1), “*soft skills are those skills which are used when one human interacts with another human*”, this professional understanding of a larger society implied the practice of soft skills.

The 2001 computing curriculum (IEEE-CS & ACM, 2001, pp. 40-42) clearly stated that university courses would need to integrate non-technical skills. It specified at least two soft skills, which were communication and working in teams. In the 2008 version, the communication and team working skills were still in focus, but with the additional skills of management and professional development (ACM & IEEE-CS, 2008a, p. 22).

Similarly, the Information System 2010 (IS2010) curriculum stated the importance of non-technical skills in the graduate. IS2010 stated: “*Students must understand that IS professionals should be able to ... collaborate with other professionals as well as perform successfully at the individual level ... [and] communicate effectively with excellent oral, written, and listening skills* (Association for Computing Machinery & Association for Information Systems, 2010, p. 8).”

Therefore, non-technical skills, especially communication skills and skills such as working in teams, were considered to be important and should be offered by the universities which develop internetworking curricula.

2.2.1.4 The current situation of computing curricula

The current issues in internetworking education are similar to what happened in the past with computing science. As enrolment numbers have reduced, the demand from the industry for IT staff has increased. One of the reasons for this situation could be seen to be related to outdated curricula.

According to the ACM/AIS joint task force:

The interest in the study of IS as a field has dramatically declined among students at most institutions in North America, Western Europe, and Oceania. Therefore, it is imperative that the IS community as a whole addresses this problem from several different perspectives, including curriculum design. The response to the enrolment crisis cannot only be based on curriculum changes; however, an outdated curriculum can be a sufficient reason to turn a prospective student away from the discipline. For other areas such as India, China, Eastern Europe, and Russia where there is growth, the dominant form has been engineering and scientific rather than business oriented; therefore, suggests curriculum design that meets global needs (Association for Computing Machinery & Association for Information Systems, 2010, p. 7)."

According to the ACM/IEEE-CS joint task force:

Today there is talk of a crisis, with enrolments having plummeted in many countries, often by as much as 60 – 70% from the peak of 2001 ... At the same time, the number of jobs in computing has risen while the supply of good graduates has fallen and some data suggests is failing to meet the demand in certain countries. The reasons for this are many and complex. However, many argue that the traditional curriculum in computing is unattractive to present-day students and that creates a challenge (Association for Computing Machinery & IEEE Computer Society, 2008a, p. 9).

Cameron (2008) suggests that those in academia should develop a new curriculum to cover more aspects of core elements in IT education. These core elements are databases, internetworking, software applications, operating systems and data storage. The new curriculum should contain all of the core elements in an integrated manner and academia should seek assistance from and build relationships with industry.

Therefore, on the development or the conduct of internetworking education, the institution should concern itself with the design of the curriculum. The attractiveness of teaching topics and their application in the real world may improve the number of enrolments.

2.2.2 Summary of discussion of model curricula

In summary, the key points that must be considered from the model curricula were:

1. Internetworking technology gained a more important role in IT education over the years. This raised a concern for the construction of proper internetworking curricula and as teaching facilities.
2. Advancement in Information Technology is rapid, which increases the demands for internetworking teaching curricula to be updated consistently.
3. Model curricula suggested building information technology knowledge by emphasising hands-on experiences; internetworking education should also follow this trend.
4. A major concern of building technical skills was mentioned in the model curricula, but they also stressed that teaching institutions should emphasise the building of non-technical skills.
5. An ongoing issue of the *computing crisis* was that the demands for internetworking staff were increased whereas the numbers in the student cohorts were reducing.

Therefore the traditional internetworking education might be revised and compared with other newer generation curricula.

2.3 Traditional curricula versus vendor-based curricula

In modern information technology education, new types of curricula, which were inspired by industrial companies, were developed. These were called vendor-based curricula or industry-based certification. There was an ongoing debate between those who supported vendor-based certification and academic institutions, which did not (Hitchcock, 2007; Ortiz, 2003). Overall, comparisons between the traditional curricula used by universities and the vendor-based curricula can be found in much of the literature (Hitchcock, 2007; Murphy, Kohli, Veal, & Maj, 2004) (see Table 1).

Table 1. Comparison of traditional and vendor-based curricula

Topics	Traditional curricula	Vendor-based curricula
Learning style	Theoretically based, claimed as educational	Practice-based, argued to be more akin to training
	Less hands-on	Hands-on training
Knowledge gained	Based on educational pedagogical theory	Recall knowledge
Learning content	Context is flexible, and were designed to fit into regular university semesters	Large amount of content, could not fit in regular university semesters
Course material	In-house selection of text-books, references, course materials	Course materials developed by industry
	Universities own the course materials	University may not own the course materials and may lose control of them
	Universities develop their own course materials	Supplied course materials, included in the program
Rate of curricula update	Slow, need review and approval from internal and external institution	Fast, regularly updated to keep up with the available products on the market. This material can be updated by the vendor when and how the vendors may decide.
	Structured audit trail, having both internal and external auditing committee	Proprietary standard, quality control entirely by the vendor company
Industrial relationship	Less influence from industry	Strong influence from industry
	Generic knowledge	Product specific knowledge
Extra cost	No extra cost	May have joining fee
	University is flexible to set the standard and requirements of the course	Standard and requirements of the course are predefined from the vendor. Vendor may require list of equipment / software licenses
Staff requirement	University staff do not need any specific certification	Vendor-certified staff only are permitted to conduct the course
	Not mandatory for staff to be regularly trained	Mandatory for staff to be regularly trained by the vendor
Other	More individual, universities may have different course implementations	Often strong sense of community; exchange between different institutions

Vendor-based curricula may answer the key suggestion points from the model curricula on the following topics:

- Vendor-based programs were updated at a faster rate and were more likely to be able to catch up with the rapid development of technologies more successfully than the traditional model.
- The emphasis on hands-on training of vendor-based curricula fulfilled the suggestions of model curricula, as the graduates should be equipped with both theoretical and practical hands-on experiences.
- The integration of vendor-based curricula into universities may reduce the gap between university education and industry requirements. Vendor-based programs have a stronger relationship with industry (Adelman, 2000b, p. 29). Graduates may likely to be more suitable for jobs than with a more traditional university education (Hitchcock, 2007, p. 95; M. L. Nelson & Rice, 2001, p. 280). Therefore, it may alleviate the *computing crisis* problem, that the traditional education cannot produce enough graduates to supply industry demand (Rajendran, 2011, p. 231).

Detractors have argued that vendor-based certifications were likely to be called *training*, not *education*, when compared to the traditional university-based curricula (Ortiz, 2003, p. 178). Major opposition comes from the more academically orientated universities. According to Schlichting and Mason (2004), survey results indicated that the common response of academic institutions to vendor-based curricula was negative.

On the other hand, the benefits of vendor-based curricula were shown (Cakir et al., 2006). Furthermore, these benefits were not just only limited to the universities and their students but also paid off for the vendors. According to Porter and Kramer (2002) the cost of developing such curricula for the vendor may be seen as a marketing cost which enhanced the reputation of the company.

As a result, much research has suggested that the universities cannot avoid the existing benefits of vendor-based curricula, even though they cannot be considered as an entirely replacement solution for university education (Adelman, 2000b, p. 29). A number of articles describe the benefit of adopting these curricula and universities may consider offering merged courses. Examples of the integration of such programs to the traditional

academic curricula were also presented and recommended (Adelman, 2000a, 2000b; Houston, Blesse, & Herrod, 2005; Rajendran, 2011; Schlichting & Mason, 2004; Veal, et al., 2005). However, universities may need to be aware of negative consequences of adopting vendor-based programs, such as the extra needs and costs to fulfil the vendor's requirements.

2.4 Cisco Network Academy Program (CNAP)

In internetworking education, the most important vendor-based curricula were developed by the Cisco, the major network equipment company. Cisco Network Academy Program (CNAP) is a complete e-learning program, that has reached a broad number of students, approximately 600,000 enrolled students, in more than 160 countries (Cisco, 2009b). It has consistently emphasised hands-on activities to help students become more familiar with networking equipment, and has been integrated into education institutions, especially universities, as an external course provider and an equipment provider. Through these strong relationships, Cisco's partnerships include many educational institutions, governments, and information technology companies. Cisco has a comprehensive role as the provider of the hardware (network equipment), software (network operations software), and people ware (through both CNAP and its commercial training partners).

CNAP offers a course at different levels which are suitable for different categories of students. Basically, there are at least two levels of coursework. This coursework is based on certification that is provided by Cisco after successful completion. The certifications have been widely accepted as global standards for most information technology companies. These certifications and coursework levels are the Cisco Certified Network Associate (CCNA) and the Cisco Certified Network Professional (CCNP).

The CCNA is marketed as a fundamental course for students to learn basic networking design and operations. It offers four sub-levels from CCNA1 to CCNA4. On the other hand, the CCNP targets the more advanced student. Preferably, but not compulsorily, students are recommended to have at least been through CCNA or an equivalent course before attempting CCNP. CCNP has the objective of raising graduates' standards to match those of qualified network administrators.



Figure 3. CNAP learning environment (Cisco, 2009b)

Figure 3 shows the learning environment of CNAP which consists of description (left) and interactive exhibition (right). The users can scroll through and find useful information, such as a glossary, from the tools bar in the lower section of the screen.

CNAP is an e-learning system which has taken the approach of using simulation software as a main hands-on tool for students. Simulation software is a tool which will be described in more detail in a later section. CNAP uses *Packet Tracer* as the software release for their online course (Cisco, n.d.-b). It allows students to have virtual experiences with networking equipment. Packet Tracer allows users to create an interconnection between different devices, virtually, without the limitation of hardware availability, e.g. variety of devices and the available number. Furthermore, networks running on different PCs can be linked together.

Although the simulation software is available, CNAP notes that there needs to be hands-on access to real equipment as well as the Packet Tracer (Cisco, 2007, p. 4). CNAP also recommended the size of a class not to be larger than 15 students per a class that conducted by one instructor, and per set of standard equipment bundle, which consisted of 15 computers, 3 routers and 3 switches (Cisco, 2000, p. 12).

2.4.1 Advantages of CNAP

CNAP offers vendor-based curricula; therefore it benefits students by presenting a professional point of view. In fact, it benefits several stakeholders in network education.

Vendors themselves can increase the number of experienced people able to use specific products; employers can judge selected employees by the same standard; employees can be recognised from their qualification which will help their career. As a result, many education institutions are looking to embrace vendor-based curricula into their course offerings (Schlichting & Mason, 2004, p. 165).

CNAP is an e-learning platform which is available to online students. Online resources can be delivered to vast numbers of students at the same time. This promotes an efficient approach to education and distribution of the same high standard of course materials.

CNAP aims to offer both practical hands-on experiences and a link to the theoretical background to students. The link between theoretical concept and practical application was also recognised in the ACM model curriculum (ACM & IEEE-CS, 2008a, p. 21). Although CNAP recommended their students should have first-hand experience on physical equipment; their approaches on a simulation laboratory were arguably an effective use of resources. A simulated laboratory may help students to learn faster (Ma & Nickerson, 2006, p. 6).

The development of new technology in networking makes the traditional university-based curriculum seem more static when compared to a curriculum constructed by a vendor-based provider. The continual development in technology drives a gradual improvement in curricula to keep pace with the changes in industrial technology (Houston, et al., 2005, p. 9). CNAP's ongoing curriculum development reflects reality in the networking sector, and is easier to implement. Therefore, students pursuing the CNAP are far more closely related to the evolution of technology than they are in the traditional curricula. CNAP also brings together CNAP instructors from a range of educational and training institutions to meet each other and to undergo professional development activities.

2.4.2 *Disadvantages of CNAP*

CNAP is a vendor-based curriculum, therefore it is network equipment brand-specific (Schlichting & Mason, 2004, p. 159). As a result, the course displays a high degree of bias towards Cisco. In other words, it is unlikely that the course will offer materials that may be applied to other vendors' equipment. Configuring a range of different vendor

devices to interoperate correctly together is a value and a useful skill in multi-vendor environments.

Educational institutions can lose control of the curriculum (Adelman, 2000b). CNAP, as a vendor-based curriculum, may have been intended to cover the overall aspects of the networking curriculum rather than focusing more deeply on theoretical concepts. This was because of an emphasis on producing more networking professionals in a short time span or of extending the knowledge and understanding of professionals in the field. Therefore it tends to be surface learning in the way that it is emphasising remembering rather than learning (Maj & Veal, 2007, p. 1). This can be shown by examining the teaching materials that influence consideration of network equipment, such as routers and switches, as “black boxes” (Maj & Kohli, 2004, p. 1). This is in contrast to constructivist educational theory, in the sense that the materials should provide enough pedagogical models for the students to understand and develop their own conceptual models. (Glaserfeld, 1989, p. 11; Kohli, et al., 2004)

Although embracing vendor-based curricula, such as CNAP, is an ongoing trend in many education institutions (Schlichting & Mason, 2004, p. 165), acquiring them infers an extra cost. There are the costs of acquiring the vendor-specific equipment and training fees for instructors to keep up-to-date. Incorrect consideration of cost requirements may lead to cancellation of the course. For example, incorrect development of training staff may incur the discontinuation of the teaching materials. This is as Houston et al. (2005, p. 6) stated below:

In addition to industry certification(s), faculty are also required to have additional instructor certification. Cisco Certified Academy Instructor (CCAI) status denotes a proficiency in delivering the instruction required to support the diverse needs of the CNAP program. To meet CCAI requirements, faculty must complete the Cisco Networking Academy Instructor Orientation Course, complete all curriculum course training (including final exams, skills tests, and demonstration of pedagogical skills), maintain the requirements for recognized industry certification, and teach each course in the curriculum. They must also participate in additional training when the online curriculum is updated. If these requirements are not successfully completed, the faculty member will lose access to the online resources (Houston, et al., 2005, p. 6).

CNAP has emphasised the usage of the online learning platform NetAcad via its website, <http://cisco.netacad.net>. However there are shortcomings in using such an environment, especially when dealing with learning management issues. Logofatu and Logofatu (2009) presented their work on developing a learning management system

(LMS) for use with the Cisco Networking Academy website. The system allows academic staff to communicate with students in more general terms as well as tracking their study records. The usage of this system was well accepted within their institution.

2.5 Internetworking education in Thailand

Evidence showed that Thai universities started adopting e-learning before 1997 (Suanpang & Petocz, 2006, p. 415), but the initiative in the Thai master plan for emphasising information technology in classrooms only commenced in 2004 (Laohajratsang, 2009, p. 541). The continuation of this emphasis was also recognised in the former prime minister's speech (Vejjajiva, 2008) and the current policy (Ministry of Education of Thailand, 2010).

Thailand Cyber University (TCU) (2004) has been set up as an initiative for the exploitation of e-learning at university level in Thailand. TCU was a cooperative project between 42 institutions; these members were Thai and international universities and public corporations. Introductory courses to internetworking were available in TCU and Thai students could register for studying the contents.

The TCU internetworking course was available in the virtual learning environment (VLE) (see Figure 4). VLE was a standard content management system (CMS) or learning management system (LMS) for e-learning. The LMS normally provided a repository for course contents, with facilities for the students to communicate to the content facilitators (lecturers) and other students.



Figure 4. Thailand Cyber University's internetworking learning environment (VLE)

The TCU course contents were available free of charge; however they may not have been regularly updated. In contrast, vendor-based courses, such as CNAP, may have been used to counter this lack of currency, but introduced an extra cost.

The number of Thai higher degree institutions registered to be CNAP training institutions increased from 1 institute in 1998 to 57 institutes in 2009. The total number of Thai higher education institutes, which were recognised by the International Association of Universities (IAU), a UNESCO-based worldwide association of higher education institutions, was 132 institutions (International Association of Universities, 2009). Hence, the number of registered CNAP institutions in Thailand increased from less than 1% to be nearly 50% within 10 years. The total number of students enrolled in these institutions between 1998 and 2009 was 14,107 students (Cisco, 2009a).

In comparison to its neighbour, the first CNAP institution in Singapore was started in the same year as Thailand, 1998, and in 2009 there were 43 institutions registered. The number of enrolled students over the same time period was remarkably more than Thailand by the figure of 24,932 students. Malaysia, which started the first institution in 1999, has reached 59 institutions with a total enrolment of 16,227 students (Cisco, 2009a).

This statistical data indicates the following points:

- Firstly, the e-learning situation in Thailand is still under-developed (Lertkulvanich, Buranajant, & Sombunsukho, 2008). Internetworking education in Thailand has more growing space. E—learning environments, such as that CNAP offered, may benefit the development of internetworking staff in Thailand. CNAP was only available in 50% of all tertiary educational institutions.
- Secondly, the number of institutions interested in conducting internetworking courses has increased, so one may conclude that more students are requiring internetworking courses.
- Thirdly, in comparison with the neighbouring countries, Singapore and Malaysia, Thailand still has a lower average ratio of students per institution. This lower number of students may indicate a potential problem within Thailand's

internetworking education system and show the opportunity for improvement, especially through new delivery models such as distance education.

Typically, LMS were traditional e-learning resources which normally had the issue of a lack of provision of hands-on practice to students (Wuttke, Ubar, Henke, & Jutman, 2008). The normal lecture courses can be replaced with self-paced study through an LMS; however the online laboratories for units that emphasised practical hands-on skills were still unavailable. Internetworking was one of the courses that strongly required significant hands-on practice, which meant accessing internetworking equipment. Normally internetworking equipment is considered to be expensive for developing countries. Thailand was no exception. In the last decade, providing such technological facilities in universities was a challenge for Thailand (Sirinaruemit, 2004, p. 135).

Furthermore, the requirement for internetworking graduates in Thailand was not only limited to their technical skills. As mentioned earlier, the ACM/IEEE model curricula also paid attention to non-technical or soft skills (see section 2.2.1.3). Corresponding to the international tendency (Chandler, 2011), Thailand's educational system also suffered from a skills gap between industry expectations and academic degrees. A study in Malaysia showed that the gap may be associated with the lack of development of soft skills (Devadason, Subramaniam, & Daniel, 2010). A recent study also confirmed that this situation also existed in Thailand (Chookittikul, et al., 2011, p. 242).

In summary, internetworking education in Thailand may be experiencing a strong push from the following two factors:

- The collaboration between universities to build the shared TCU online e-learning environment, and
- The increasing adoption demands for e-learning environments from vendor-based curricula such as CNAP.

Although the content of internetworking courses was available online, the students' need for access to equipment still remained a challenge for Thailand (Schiller & Liefner, 2007, p. 554). Thai universities may have to decide between the various options for equipment provision. Therefore issues that remain for internetworking education in Thailand are:

- how to provide affordable means of access to internetworking equipment for the growing number of students, and
- how to ensure that the new graduates attain sufficient levels of soft skills or non-technical skills.

Therefore, studies that investigate the suitability of different equipment provision modes and the study on the appropriateness of teaching soft skills are needed.

2.6 Soft skills or non-technical skills

Definitions of soft skills, non-technical skills or professional skills were not given clearly and became a cause of confusion and complication in earlier studies (Daniels, et al., 2011, p. 145). Tannahill (2007, p. 1) gave the definition of soft skills as the skills which were used when someone interacts with another human being. In this research, the author would like to focus on four major types of soft skills, which are defined below:

- Communication skills: The ability to make a concise interaction with a range of audiences about technical issues and solutions in all forms: face-to-face, written or electronic communications (ACM & IEEE-CS, 2008a, p. 22; Quinn-Hughes, Fisher, & Dooling, 2008)
- Leadership skills: The graduate is *“able to develop the sense of team purpose and direction to achieve team goals* (Taylor & Woelfer, 2009, p. 105).”
- Teamwork skills: The ability to work as part of the team communally and successfully (ACM & IEEE-CS, 2008a, p. 22; Taylor & Woelfer, 2009, p. 105).
- Emotional intelligence *“concerns the ability to carry out accurate reasoning about emotions and the ability to use emotions and emotional knowledge to enhance thought* (Mayer, Roberts, & Barsade, 2008, p. 511; cited in Quinn-Hughes, et al., 2008, p. 4).”

These skills were mentioned in a number of publications (Chookittikul, et al., 2011, p. 24; Devadason, et al., 2010; Joseph, Ang, Chang, & Slaughter, 2010) including the recommended curricula (ACM & AIS, 2010; ACM & IEEE-CS, 2008a).

The fast developing pace of technology required that science and engineering curricula were focused upon enhancing technical skills. Such skills were, and are, essential for students to enable them to further their careers. Computer internetworking, as part of science and engineering education, also followed a similar path. However, technical skills alone were not able to fulfil the requirements of a successful internetworking career. This is because they were only a part of the overall picture, as employers seek combinations of both skills (Lewis, Smith, Belanger, & Harrington, 2008, p. 91; Sumner & Yager, 2008, p. 97). Soft skills, non-technical skills or professional skills are another set of important skills for the work place. They consist of many sub-sets of skills, for example, communication skills, team working skills, emotional related skills, leadership skills, and management skills. The requirement of soft skills and also the capability of teaching institutions to supply these skills are still being investigated (Chandler, 2011; Chookittikul, et al., 2011). The following questions are parts of this debate:

- What are the specific soft skills that are most required by industry?
- What is the percentage breakdown between technical and non-technical skills that industry is expecting from new graduates?
- How can academic institutions help in building these skills and
- What are new graduates' opinions about these skills?

The following section discusses some previous literature related to different aspects of soft skills.

2.6.1 Industry point of view and their requirements on soft skills

Industry requirements for skills are a major concern, especially when discussing soft skills. Previous research has evaluated soft skills required by industry and focused upon job advertisements as indicative of industry needs (Litecky, Prabhakar, & Arnett, 2006; H. J. Nelson, Ahmad, Martin, & Litecky, 2007). Academic papers and industry literature have also noted the need for soft skills (Huang, Kvasny, Joshi, Trauth, & Mahar, 2009). Yet other research has used interviews to identify industry skill requirements (Joseph, et al., 2010).

Litecky et al. (2006) investigated information technology (IT) and information science (IS) job advertisements from 1990s and 2000s from both a technical and a soft skills' employer perspective. The research found that technical skills were used extensively in the advertising and recruiting processes, however the actual hiring decision was made from the judgement of the soft skills possessed by each candidate (Litecky, et al., 2006). Moreover, Nelson et al. (2007) developed a method to analyse IT job advertisements by employing an automated process, and comparing the different requirements of smaller and larger scale corporations. This research concluded that both technical and non-technical soft skills are essential for employability. It is also important that educational institutions continue to provide both technical and soft skills in order to comply with market demands.

Huang et al. (2009) identified IT skills requirements from three categories of literature, namely academic papers, practitioner literature and job advertisements. The research divided the skill sets into technical, business and humanistic skills. This analysis concluded that academic literature emphasised non-technical skills (business and humanistic) as business needs, while practitioner literature tended to emphasise technical skills whilst job advertisements focused upon all skills equally.

Some research may identify the soft skills which are required from the industry by direct interaction with practicing industry professionals. Benamati and Mahaney (2007) interviewed thirteen IT executives from American companies about their opinion of the requirements for new entry-level IT workers. The study found that non-technical skills, especially leadership and communication skills are the most desirable. Similarly, Tannahill (2007) confirmed this emphasis on communication and team working skills. Taylor and Woelfer (2009) interviewed IT project managers from five American companies and identified the skills and their learning sources needed to become a project manager. Furthermore, Joseph et al. (2010) confirmed the need for soft skills by interviewing senior IT workers. They discovered that they could categorise many difficult situations that required soft skills to solve. Basically, the skills that were most mentioned from the industry were:

- Communication skills
- Team working skills
- Leadership skills

Tannahill's (2007) study of job advertisements on the Internet revealed a number of jobs requiring the candidate to have soft skills. Although the study found that most employers were not specific about the requirement for soft skills on the job posting, there were some interesting facts as evidence that soft skills were actually important. Firstly, the study found the bigger companies tended to advertise more of their soft skills requirements. Secondly, more management levels were required to have soft skills than non-management levels. Thirdly, the higher level of education posted on the job advertisement referred to the higher demands for soft skills, which were reflected by the increasing number of posts advertising the requirement for soft skills. Fourthly, the increasing number of experience in years required in the advertisements revealed a higher chance for the post to have soft skills requirements.

Bleek et al. (2005) pointed out that industrial experience of the instructor was also an important factor. They were also concerned about offering an opportunity for students to build their presentation skills through laboratory tasks, which is an important skill from an industrial perspective.

These ongoing research studies show the importance of soft skills from both industrial and academic perspectives.

2.6.2 Soft skills development in academic institutions

The importance of soft skills has been demonstrated in the previous section. It is not only that soft skills are important from an employability standpoint, but that they also are significant indicators of the likelihood of academic achievement. Lewis et al. (2008) found that there was a strong relationship between the possession of soft skills and the intention of computer science students to continue with their studies. Hence, this may create expectations for academic institutions to assume responsibility in where and how soft skills may be taught.

Major IT professional organisations, such as ACM, IEEE, ACS and others, have already recognised the importance of soft skills development. For example, some soft skills were already listed in a certification program called Information Systems Analyst (ISA), which was recognised by the three main United States IT organisations: Association for Computing Machinery (ACM); the Association of Information Technology Professionals (AITP); and the Association for Information Systems (AIS) (Sumner & Yager, 2008). The model curriculum for software engineering, from the ACM in 2004,

recommended including soft skills elements in computer science curricula (IEEE-CS & ACM, 2004). The ACM described soft skills as professional practice, and also referred to a survey result from the National Association of Colleges and Employers (NACE) in 2003, which pointed out that soft skills, for example communication, teamwork, and interpersonal skills, were rated as important skills (IEEE-CS & ACM, 2004). An Australian Computer Society survey (ACS, 2005) in 2005 also revealed the shortage of soft skills development, such as communication and project management skills. The new Edith Cowan University (ECU)'s (2010) undergraduate curriculum framework also integrated soft skills in its desirable graduate attributes. A similar recognition may also be found in the referencing of the Project Management Institute (PMI)'s list of skills (Taylor & Woelfer, 2009). However, the standard ways of developing or teaching these skills were not presented.

A combined ACM and AIS work force created recommendations for Information Systems curricula (IS2010) (ACM & AIS, 2010) and specified the expected knowledge and skills of IS graduates under two categories: foundational knowledge and five non-technical skills types. However, the model curriculum did not specify in detail how these foundational skills could be incorporated in the implementing curricula.

The ACM (ACM & IEEE-CS, 2008a, p. 22,) also recognised non-technical skills as additional transferable skills in its "Characteristics of graduates" section. Correspondingly to the computing curriculum (CC2001) (IEEE-CS & ACM, 2001, p. 17,), it also stated the value of professional practice, such as communication and team working.

Basically, the soft skills that were mentioned most frequently in model curricula were:

- Communication skills
- Team working skills

One way of teaching soft skills is to integrate them into the IT curriculum and let students have a chance to develop them over time. McIntosh-Elkins and Klein (2008) described an initiative which integrated teaching of technical skills and training of non-technical skills throughout their program, called IT Fellows. IT Fellows is an undergraduate program integrating the professional perspectives skills, such as job interviewing and communication skills, with the normal technical knowledge taught in a

university environment. It offers a chance for first year students to attend a specialised training session called the Leadership Academy, where the content of the course introduces the first year students to job-related aspects such as interviewing and team work. The program also offers a chance for the selected students to work part-time on campus with various help-desk related positions as internships. The value of the program to industrial requirements is clear as industry seeks developed soft skill sets from new graduates.

Capstone courses were also being introduced to computer-related courses. Brown, Lee and Alejandre (2009) showed the example of a multi-disciplinary project-based course showing collaborative work from different student majors. The study raised some concern about academic staff ability to integrate soft skills within the original coursework. A model curriculum also mentioned the use of capstone units in teaching professional skills; however, the correct period of adoption is vital as junior students may not sufficiently matured (ACM & IEEE-CS, 2008a, p. 92).

The use of multi-disciplinary group work was also showed as a benefit for training soft skills. Brown et al. (2009) introduced a multi-discipline capstone course for computer science, education and media design students. They demonstrated using this course by conducting joint projects by groups of students from different backgrounds. The aim of the project was to develop a pedagogically suitable computer games for K-12 education. This work also demonstrated concerns about integrating soft skills into computer science curricula, especially team working and non-technical communication skills. Students involved experienced some group work-related difficulties, such as controlling aspects of the software and task management roles. The article suggested that the technical students should also have learned to build skills to work with requirements from non-technical perspectives and also had to consider the project as being requirement driven rather than technically driven. Their work noted a problem called “technical arrogance”, by which technically confident team members had the effect of making other less adept team members feel inferior.

Another approach to the teaching of soft skills is to include them in separate elective units; student will have choices to enrol and learn about their importance and to take part in soft skills development. As an example, Blume et al. (2009) taught elective units in a computer science course, which were designed to build basic soft skills, especially communication skills.

The use of laboratory sessions to build soft skills was also presented. Yuan and Zhong (2010) claimed that soft skills can be built while conducting network laboratory sessions. Examples of these skills that can be learnt during the lab are team working and the comprehension and interpretation of technical documents. The paper explored student opinions about learning soft skills during seven laboratory sessions.

Alternative opinions exist about the ideal means of teaching soft skills, whether to integrate them in technical teaching units or to teach them separately in non-technical units (Devadason, et al., 2010, p. 325). There are different results from the literature. Lewis et al. (2008) suggested integrating group or team work within in-class exercises in order to build soft skills. However, interviews of IT project managers from five American companies, about the sources of their soft skills, suggested another way (Taylor & Woelfer, 2009). The results from the interviews promote formal training of soft skills in separate teaching units. Some believe that formal training methods are less practical when compared to the experiential learning process, but the foundation that they provide is essential (Taylor & Woelfer, 2009). Skills have to develop from training and practice (Downey & Babar, 2008, p. 2). Therefore, academic institutions still seek to adopt the best practices of teaching soft skills; the question of the best means is a valid point of ongoing argument.

It can be concluded that soft skills were also emphasised from an academic perspective, as they can be found in a number of recommendations in model curricula, but there were no absolute guidelines for implementing such training courses. At least two categories of soft skills training were recognised, embedded or integration and stand-alone methods. The methods recommended by each institution remained different. Further research on this topic is needed.

2.6.3 New graduates' opinions of soft skills

Opinions from new graduates may reflect the need for soft skills and the current status of academic institutions teaching soft skills. A number of researchers studied the opinions of newly employed graduates. This section shows some results from the literature.

Sumner and Yager (2008) studied graduates of Management Information Systems (MIS) course about their perspectives of the ways in which their course integrated technical and soft skills building. They found that newly employed graduates rated soft

skills as the most important factors contributing to their success in jobs. Similar results were confirmed by the study of graduates from IT departments, who have worked recently in IT related positions for a few years (Nagarajan & Edwards, 2008). These two studies identified the list of soft skills that new graduates felt were important; for example, team working skills, leadership skills, management skills and communication skills. Hence, soft skills were clearly recognised by graduates as an important element to be built during their degree.

Students may not realise the priority of soft skills compared with technical skills. Additionally, difficulties may also arise when trying to measure the value of soft skills in new graduates in comparison with technical skills. One way of measurement is by using an observation technique. In Chinn and VanDeGrift's work (2007) the student perceptions of graduated hiring decisions were investigated. Using an observation technique, they collected statistical data of IT students' decisions when asked to make hiring choices in role plays. The observation technique was also used to monitor the changes in students' hiring decisions before and after a group discussion activity. The results showed that students valued soft skills as the second most important factor when compared to technical skills.

Students may value technical skills more highly than soft skills because they also lack experience in applying their newly learnt technical skills. This can be shown by another measurement technique of tracking student response times when they faced difficult situations requiring utilisation of soft skills. Joseph et al. (2010) measured this response and compared the result between first year IT students and experienced IT workers. They found a significant difference between these two populations. Students used more time than experienced IT workers and also provided lower quality responses to the situations. This study demonstrated not only a variety of measurement techniques but also confirmed the need for soft skills development in IT students.

2.6.4 Methodology used in study of soft skills in IT related education

Studies of soft skills in IT related education is still in an exploratory state (Nagarajan & Edwards, 2008; Taylor & Woelfer, 2009). Evidence supporting this claim can be found by considering the use of various research methodologies in the literature. This section will group various studies together by the techniques used.

Various research studies have shown the use of open ended interview techniques. For example, qualitative interview technique has been used in a number of study (Benamati & Mahaney, 2007; Downey & Babar, 2008; Nagarajan & Edwards, 2008; Taylor & Woelfer, 2009). Joseph et al. (2010) also used interview technique as part of their study which gathered difficult IT situations that required significant soft skills to solve. These qualitative open-ended interview techniques are great for exploratory research as they offer the possibility of collecting in-depth details. However, they also demonstrate the need for confirmation studies using other techniques, for example, quantitative methods.

Moreover, critical incident technique (Flanagan, 1954) was used as a method to elicit work-related difficult situations. Bradley (1992) defined a critical incident as a real happening where the cause and the effect of the event are tremendously clear and relevant to the subject under study. The critical incident, in the perspective of soft skills, refers to a real case that occurred and required high levels of interpersonal skills on the part of the person attempting to solve the problem. Joseph et al. (2010) used this method to capture the difficult situations that demand high levels of soft skills from senior IT managers. Similarly, Taylor and Woelfer (2009) used this method to identify the learning source of soft skills. Critical incident technique is a good technique to capture a situation from experienced IT persons; however, when applied to students or new graduates, who may lack such experience, the usage of critical incident technique may be found to be ineffective.

Furthermore, there is a lot of literature which considers the usage of data exploration techniques, such as grounded theory. Martin and Turner (1986, p. 142,) defined grounded theory as the method that explains the common characteristic of the current topic of study by using concrete evidence derived from collected data. Therefore, in other words, grounded theory is the method to discover theory from data (Glaser & Strauss, 1967, p.1). Grounded theory was used in order to analyse the collected data in a number of projects described in the literature. Nagarajan and Edwards (2008) used

grounded theory to analyse the collected data and built a theory of the relationship between non-technical skills of recent IT graduates and their university studies. Joseph et al. (2010) also used the benefit of collected data to form groups of problems that seemed difficult to resolve. Huang et al. (2009) also benefited from gathering a large amount of data to form a group of skills requirements. The use of grounded theory may suit a large amount of data in the exploratory stage, which the theoretical outline was still undiscovered. However, it may not be suitable for those experiments that will have only limited data.

2.6.5 Needs for further research

In conclusion, research literature considered IT students as a whole while studying their soft skills. Particularly, the software engineering or programming side of computer science has been extensively researched. Software engineering education is primarily focused upon project-based assignments and tasks. Therefore, it could be argued that software engineering students may have an earlier opportunity to build their soft skills. This also can be demonstrated by the number of software engineering courses which introduce some ideas of project management as part of their content. This often includes the concepts of software requirement elicitation, customer management, software project development paradigms, project management, and prioritisation skills. However, internetworking students, who tend to focus more on understanding of individual technologies and building up their technical skills, may have a comparatively late chance of building their perception of soft skills. Therefore, the study of soft skills, particularly by internetworking students, may need to be developed.

Secondly, the previous literature focused upon the perceptions of recent and experienced IT graduates, to gain their view of the soft skills required in their workplaces. However, the study of current ongoing students at different levels may provide diverse answers to the question. For example, comparing the students' perceptions between different levels may reveal any weak points of the overall internetworking curriculum.

Furthermore, literature on research so far undertaken tends to show that most studies were exploratory, with respect to their use of grounded theory and research methodologies such as qualitative interviewing. This illustrates the need for results to be confirmed through the application of a number of different methods, if they are to be

considered as reliable. Sustained further research, beyond mere exploration, is needed in this area.

2.7 Related educational theory

Since this research related to educational aspects of internetworking, there is a need to consider relevant educational theory. From an educational standpoint, learning can be regarded as the cognitive process of understanding knowledge (Tollinger et al., 2005; Tsai, Compeau, & Haggerty, 2004). A simple word as “understanding”; however, may describe learning outcome in a generic context, but is ambiguous. For example, the difference between remembering a given instruction and realising the purpose of the instruction can be considered as a possible interpretation of understanding. Various educational theorists have proposed different taxonomies to categorise these different levels of cognition in an attempt to provide a precise definition of understanding.

2.7.1 Bloom’s taxonomy

Bloom (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) was well-known for his classification of cognitive levels. In his classification, he divided the level of expected behaviour of students into six levels. Bloom preferred to call his classification a taxonomy as each cognitive level is hierarchically related. His *taxonomy* shows a more ordered relationship between each level rather than a *classification*. This hierarchical order may be referred as Bloom’s ladder (Warner, 2004), as by analogy the learners need to climb, or develop themselves, from the first step of ladder to higher ones. Therefore, the level of student understanding needs to be developed from the lowest level to the highest.

In order, from lowest to highest, these six Bloom’s levels are (Starr, Manaris, & Stalvey, 2008):

1. Knowledge or recall: learners can recall or memorise facts and principles.
2. Comprehension: learners can interpret and explain the knowledge in their own words
3. Application: learners can apply the knowledge to a specific situation

4. Analysis: learners can identify the component of the knowledge in separated parts and in an organised structure to help understanding
5. Synthesis: learners can combine the separated parts of knowledge to form whole concepts, or to create a new meaning or structure
6. Evaluation: learners can make a judgement and compare the idea or materials

Each level of the taxonomy can be subdivided to sub-levels which dependant upon level of detail required in the classification process. For example, the first classification (knowledge) can also be subdivided from the lowest level as knowledge of specific facts, trends, methodology, principles and generalisation, and theories and structures.

Anderson et al. (2001) present the revised version of Bloom's famous taxonomy by separating the element of knowledge depth into a second dimension. This process renders the taxonomy amenable to descriptions via a two dimensional table from *knowledge perspective* and *cognitive process perspective*.

2.7.2 Structure of the Observed Learning Outcome (SOLO) taxonomy

The Structure of the Observed Learning Outcome (SOLO) taxonomy was based on the observation of learners doing school-based tasks, and the fact that the learners showed a similar pattern or 'learning cycle' when they were learning those tasks (Biggs & Collis, 1989, p. 152). SOLO categorised learning patterns into three stages and five levels.

1. Previous stage: described the stage of learner before entering the current learning cycle. This stage is lowest level of abstraction and more focused on the concrete.
 - 1.1. Pre-structural: the given tasks are engaged but learner is distracted by irrelevant aspects.
2. Target stage: described the learning stage that is desirable and could be set as an objective of the tasks.
 - 2.1. Uni-structural: the learner is focused on the relevant domain but can work with only one limited aspect.
 - 2.2. Multi-structural: the learner can work with various aspects but shows no sign of knowledge integration.

- 2.3. Relational: the learner can integrate various aspects and shows the whole coherent structure of meaning.
- 3. Next stage: describes the stage that where the learners have more abstraction than the requirement of the tasks.
 - 3.1. Extended abstract: the learner can generalise and apply the knowledge to higher abstraction level.

Unlike Bloom's taxonomy which was modelled from the ability of learner to manipulate the knowledge, SOLO modelled the learning process from a construction of learning structure.

2.7.3 Comparison between SOLO and Bloom's taxonomy

SOLO and Bloom taxonomies have been used as principles in computer science for both guiding of learning and assessment designs (Clear et al., 2011; E. Thompson, Luxton-Reilly, Whalley, Hu, & Robbins, 2008; Whalley et al., 2006). Particularly, they have been used to categorise learners' competency. The similarity of these two models was that they model the learning procedure, starting from the concrete or most tangible level and building up to the more abstract level. However, both models focused on slightly different aspect of cognition (Schrire, 2006, p. 65). SOLO taxonomy focused on the construction process and assimilation state of the knowledge that learners encountered, whilst the Bloom taxonomy focused on the ability of learners to utilise the knowledge gained.

The SOLO taxonomy may be assessed from quantifiable learning evidences (hooked-on-thinking, 2011, p. 1). For example, learners can be classified as *multi-structural* or *uni-structural* from the number of relevant aspects of knowledge. On the other hand, Bloom's taxonomy determined on the ability of learners to utilise the knowledge whether to just remembering (*recall*) or can be able to reproduce the meaning (*comprehension*), apply them to other situation (*application*) or to be able to generate the new knowledge (*synthesis*).

Bloom's taxonomy was not developed for university teaching purposes or for assessing the learners' learning outcome, but for selection of appropriate examination tasks (Brabrand & Dahl, 2009, p. 534). Furthermore, assessment items in Bloom's taxonomy have to be designed specifically to measure each cognitive level, whilst different

cognitive levels can be detectable by single SOLO assessment items (hooked-on-thinking, 2011). The measurement of students' performance with SOLO taxonomy showed an acceptable degree of consistency, with weaker students less likely to be classified in the higher SOLO category (Whalley, et al., 2006, p. 9). Hence, the usage of SOLO taxonomy gained more popularity for student evaluation purposes, as it was shown to be more suitable than Bloom (Koshinen, 2007). Teachers may have found Bloom's taxonomy was difficult to apply to assessment (E. Thompson, et al., 2008, p. 1) and felt more comfortable to use SOLO (hooked-on-thinking, 2011) because of its focus on tangible evidence-based structure.

In contrast, the SOLO taxonomy may not be able to distinguish performance at higher cognitive levels. As in Table 2, which shows the comparison between different cognitive levels of the Bloom and SOLO taxonomies, differences between *uni-structural* and *multi-structural* of SOLO was small when compared to Bloom's levels (Schrire, 2006, p. 63). Furthermore, students in SOLO's *multi-structural* level did not necessary tend to show their understanding by rendering the knowledge in a new structure, or *synthesis* in Bloom's definition (Whalley, et al., 2006, p. 7). Moreover, both taxonomies are heavily cited in the literature (Brabrand & Dahl, 2009; E. Thompson, et al., 2008; Whalley, et al., 2006).

Table 2. Comparison of cognitive levels of Bloom and SOLO (Schrire, 2006, p. 63)

	Bloom's taxonomy	SOLO Taxonomy
Cognitive levels	Comprehension Application Analysis	Uni-structural Multi-structural
	Application Analysis Synthesis	Relational
	Synthesis Evaluation	Relational Extended abstract

In summary, the similarities between Bloom and the SOLO taxonomy were:

- Cognitive level of understanding can be categorised in a hierarchical order, from lowest to highest.

- Basic cognition started from concrete element, *recall* in Bloom and *uni-structural* in SOLO, to the more competence level which described as the ability to show the relationship between concrete elements, *analysis* in Bloom and *relational* in SOLO.
- The highest cognitive level of both models are described as higher abstract levels, by the ability to be able to generalise the knowledge in SOLO and the ability to be able to judge the knowledge in Bloom.

The differences between these two models were:

- Bloom focused on the ability of the learners in order to utilise the gained knowledge, to memorise, describe, apply and eventually to criticise it. On the contrary, SOLO recognised the learning process from the structure of knowledge, i.e. from unstructured learners, single aspect learners, multiple aspects learners and eventually learners who can create a relationship between different aspects.
- SOLO developed from the need for classification of learners in assessment processes; whereas, Bloom developed from the need for classification of the assessment materials. Hence the classification between categories in SOLO was clearer and more measurable to the performance of learners than Bloom.
- SOLO specified the outcome of learning process as targeting a range of classification, which separated the understanding into three levels, uni-structural, multi-structural and relational, whilst Bloom did not specified any target of the learning process.

2.7.4 Concrete and abstract learning

The work of Piaget (1952) was significant in the twentieth century (Glaserfeld, 1989, p. 4). Piaget stated four stages of cognitive development or learning process from childhood to adulthood (Biggs & Collis, 1989, p. 155; Hoy, 2008, p. 39). Table 3 shows the stages of development in cognition from Piaget's theory.

Table 3. Piaget's stages of Cognitive Development (Hoy, 2008, p. 39)

Stage	Approximate age	Characteristics
Sensori-motor	0-2 years	<ul style="list-style-type: none">• Begins to make use of imitation, memory and thought.• Begins to recognise that objects do not cease to exist when they are hidden• Moves from reflex actions to goal-directed activity.
Preoperational	2-7 years	<ul style="list-style-type: none">• Gradually develops use of languages and ability to think in symbolic form.• Able to think operations through logically in one direction.• Has difficulties seeing another person's point of view.
Concrete operational	7-11 years	<ul style="list-style-type: none">• Able to solve concrete (hands-on) problems in logical fashion.• Understands laws of conservation and is able to classify and seriate.• Understands reversibility.
Formal operational	11-adult	<ul style="list-style-type: none">• Able to solve abstract problems in logical fashion.• Becomes more scientific in thinking.• Develops concerns about social issues, identity.

Piaget (1952) originally believed that children's learning processes were separated as discontinuous stages. However, present opinions emphasise its discontinuities less and represents them more as continuous stages (Siegler, 1998). Further, the ability of learners could also depend on their expertise (Siegler, 1998) and cultural differences could influence the outcomes of the learning process (Berk, 2005).

In summary, some education theorists believed that the learning process started from the simplest concrete level to more abstract levels of complexity. Concrete was defined as the tangible tasks that likely to be able to be completed hands-on, whilst the abstract level was defined as a conceptual theory or intangible form of knowledge that cannot be demonstrated in a hands-on manner. Although expertise and cultural factors could affect learning outcomes, the learning process still follows the development cycles from lowest to highest. Education theorists, Piaget (1952), Bloom (1956), and Biggs and Collis (1989) defined higher order learning as being more the abstract level, which

indicated the ability to generalise, criticise or to develop greater concerns to build broader knowledge.

2.8 Command Line Interface and Graphical User Interface

In internetworking command line interfaces (CLI) remain as the common method of human computer interaction, used when input is limited to the keyboard. The CLI was originally developed for use by experienced internetworking professionals (Maj, et al., 2005). However, graphical user interfaces (GUI) are becoming increasingly available for user-input methods in current ordinary computers. Table 4 give a basic comparison between CLI and GUIs.

CLI and GUIs are based on different learning skills. CLI users need recall memory to remember commands, whereas GUIs require recognition and interpretation of symbols and commands (Durham & Emurian, 1998). In general computer operation and teaching purposes, a number of researchers have agreed that novice users were more satisfied with a GUI than CLI (Chin, Diehl, & Norman, 1988; Hasan & Ahmed, 2007; Maj, et al., 2005; Seneviratne, 2008; R. S. Thompson, Rantanen, Yurcik, & Bailey, 2007). However, research also found that both CLI and GUI users need to be re-trained after a period of disuse and users of GUIs may take more time to perform the task (Durham & Emurian, 1998). Durham and Emurian (1998) tested CLI and GUI interfaces with novice users. They tracked the number of errors comparing CLI and GUI on the original and retention usage.

Table 4. General comparison between CLI and GUI (Computer Hope, n.d.; Sisler, 2000)

Topics	CLI	GUI
Ease of use	Recall memory Novice user found it was not comfortable working with CLI	Recognition Novice user found to be more comfortable
Control	Users have more control with single line command	GUI gives less ability to control to users
Multitasking	Typically, CLI doesn't provide the ability to view multiple activities at once.	GUI can used to monitor multiple activities on the same screen by viewing at different windows.
Speed	CLI gives more speed for user to execute a command	Control via GUI is typically slower than CLI
Resources	CLI consumes less resources	GUI consumes more processing resources, in order to provide the same capability as CLI.
Scripting	CLI allow the user to create a script of sequential commands to perform pre-defined tasks	GUI lacks the ability to take a series of pre-defined set of commands. Although users may be able to create a shortcut of commands, it is not a script that can run several commands.
Remote access	CLI or text-only manipulation can be used in remote access environments.	Remote access GUI is becoming popular; however, interaction speed and availability is till limited when compared to CLI.

In internetworking, CLI was considered as a main access method to internetworking equipment, which mostly does not have monitors or any input devices attached to them. CLI commands were considered to be mainly suited for use by internetworking professionals configuring these devices (Maj, et al., 2005). Internetworking equipment was normally accessed via a terminal login by CLI, locally through special console cables. A simple text-based CLI terminal to control internetwork equipment is shown in Figure 5.

```

Router3>
Router3>en
Router3#show ip route
Codes: C - connected, S - static, I - IGRP, 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, E - EGP
        i - IS-IS, 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 20.1.1.1, 00:00:22, Ethernet1/0
C       200.200.3.0/24 is directly connected, Loopback0
R       10.0.0.0/8 [120/1] via 20.1.1.1, 00:00:22, Ethernet1/0
C       192.168.2.0/24 is directly connected, FastEthernet0/0
Router3#
Router3#
Router3#

```

Figure 5. Text-based CLI terminal for controlling network equipment

Unlike the local control of network equipment, a remote login to a text-based CLI console can be made available via network IP connectivity. Hence if the remote session were to lose the connection to the network via the changing of the network (IP) address, for example, then the text-based control would be terminated. However, it would still be possible to use an out of band method, such as a modem via a router's auxiliary port or through the use of a specific console server. Similarly, a separated IP connectivity is required in order to access the console servers (Opengear, 2011).

Some text-based CLI commands in internetworking equipment are already equipped with adaptive input. The Cisco Internetwork Operating System (IOS), for example, allows users to fill part of commands and adaptively parse them as correct full-version commands. *“Although the above [adaptive] command lines have reduced the cognitive load on the user, it seems that novice computer users prefer the GUI* (Seneviratne, 2008, p. 4).” Furthermore, novice learners may found that text-based responses of the commands are verbose and they may easily lose track of what they have already done (Maj, et al., 2005).

On the other hand, GUI access to internetworking devices is also possible. Cisco's Secured Device Manager (SDM) allows users to access, manage and control Cisco's network devices (Schluting, 2010). Figure 6 shows an example screen shot of this SDM software.



Figure 6. Cisco's SDM, a GUI for manage Cisco's network devices (Schluting, 2010).

Similarly to remote text-based CLI access, GUI access to Cisco routers is still restricted as they still require network connectivity. Hence loss of the connectivity will be regarded as terminated GUI session. Locally connection to the GUI through a console port is not available.

In summary, CLI was, and still is, extensively used as a main emphasis in internetworking courses, despite not being designed for novice learners (Maj, et al., 2005). CLI could provide a suitable facility such as remote access to devices, and have been found in a number of remote access learning facilities (Stretch, 2008; Dan Wendlandt, Casado, Tarjan, & McKeown, 2006). CLI consume less computing resources and could provide powerful control of network devices; however, their pedagogical value may be less than that of the GUI, especially when one is concerned with overall network visualisation.

We found that the textual interface allows users to better control the analysis of details of the data through the use of rich, powerful, and flexible commands while the visual interface allows better discovery of new attacks by offering an overview of the current state of the network (R. S. Thompson, et al., 2007, p. 1).

Furthermore, text-based responses from CLI may considered as somewhat verbose (Maj, et al., 2005), displaying unnecessary on-screen information and providing poor pedagogical value for the students. Students needed to relate different information to achieve higher order learning (Biggs & Collis, 1989; Bloom, et al., 1956). Hence the need for internetwork teaching tools which are concerned with pedagogical value is still valid.

The author of this thesis has demonstrated the integration of such multimedia-rich tools into a remote learning platform (Makasiranondh, Maj, & Veal, 2010a, 2010c). The learning environment presented integrated the pedagogical value of rich teaching tools such as state model diagrams (SMDs), Cisco's Secure Device Manager (SDM) and basic remote operation tools CLI. These articles are presented as part of this thesis and may be found in Appendix F.3 and F.5.

2.9 State Model Diagram (SMDs)

2.9.1 Usage of SMDs in internetworking education

Models have been used in computer engineering to capture and conceptually display system behaviour, flow of data and protocol procedures for a long time, as in other engineering disciplines. Examples of these models are the data flow diagram (DFD), object-oriented modelling, sequence diagrams and many more. However, these models are often not fully integrated with the data extracted from networking equipment. Not showing the physical topology of the network may cause students to struggle to understand the modelled concepts. Hence, having a specific model that performs these functions will help novice students.

In networking education, teaching interconnection between computers, switches and routers is one of the common teaching methods. A number of education materials have treated these devices as "black boxes" (Maj & Kohli, 2004). As black boxes, the internal structure or functions are unknowns for students. This conflicts with accepted educational theory that says the student may need a conceptual model to understand fully what the instructor is trying to convey. Therefore, when models are used in networking education, they should be open enough for the student to see the conceptual foundations.

In light of some of these issues, State Model Diagrams (SMDs) were proposed by Maj et al. (2004), as a network engineering tool to provide hierarchical levels of information, conceptual models and visual aids. SMDs have been successfully integrated into university-based courses and compared to vendor-driven curricula (Maj, et al., 2005). They also have been extensively evaluated by on-campus students, many of whom are international (Maj & Veal, 2007). Results from previous studies (Maj, et al., 2005; Maj & Veal, 2007) show positive sides of using SMDs integrated with the teaching process. However, the SMDs may still be further developed. For example, the SMDs might be

improved by implementing them independently from any vendor-specific equipment or proprietary protocol (Maj, et al., 2004, p. 14). Also, the SMDs have yet to be evaluated against other delivery methods, such as software simulation and the remote access laboratory. This delineates an area that needs further research and development.

SMDs are developed as language independent tools for teaching internetworking. They were used with international students from India, China (Maj & Veal, 2007, p. 206) and Japan (Akamatsu, Ohtsuki, & Maj, 2007). Hence the use of SMDs by Thai students should not result in misinterpretation due to language problems.

Previous evaluation of SMDs is grounded on paper-based diagrams only (Maj & Veal, 2007, p. 205). Figure 7 shows a paper-based example of routers' information set out on SMDs unfolding Routing Information Protocol (RIP). The diagram shows different layers of information from layer 1 (physical), layer 2 (datalink) and layer 3 (network). Paper-based SMDs can be used with traditional face-to-face classes and hands-on laboratories in an efficient manner. However, to apply them to distance learning course delivery methods, the development of software-based SMDs has been initiated. Communication protocols, such as Telnet, have been used as media for gathering network device information. Figure 8 shows the first version of SMD software via the Telnet protocol. The command line interface (CLI) in the first version captured the same information as in the paper-based format. Despite the similarity of information from software- and paper-based SMDs, CLI commands used in the first version is still proprietary to specific vendors. This indicates needs for developing the SMDs software by using different approaches.

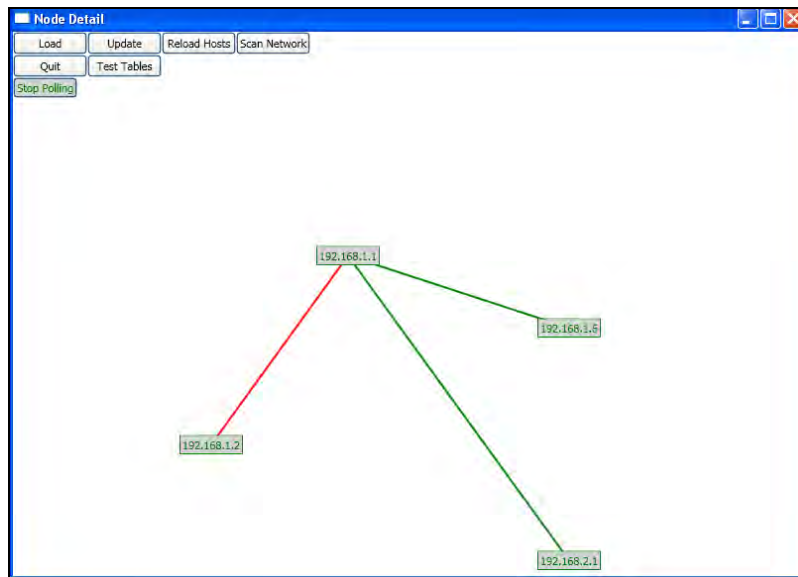
Router1																																				
OSI	Implementation																																			
Layer 3	<table><tr><th colspan="7">Routing table</th></tr><tr><th>Route learnt by</th><th>Destination IP</th><th>Administrative distance</th><th>Metric value</th><th>Next-hop IP</th><th>Entry age</th><th>Interface</th></tr><tr><td>C</td><td>192.168.1.0/24</td><td></td><td></td><td></td><td></td><td>Fa0/1</td></tr><tr><td>C</td><td>192.168.3.0/24</td><td></td><td></td><td></td><td></td><td>Fa0/0</td></tr><tr><td>R</td><td>192.168.3.0/24</td><td>120</td><td>1</td><td>192.168.2.2</td><td></td><td>Fa0/0</td></tr></table>	Routing table							Route learnt by	Destination IP	Administrative distance	Metric value	Next-hop IP	Entry age	Interface	C	192.168.1.0/24					Fa0/1	C	192.168.3.0/24					Fa0/0	R	192.168.3.0/24	120	1	192.168.2.2		Fa0/0
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192.168.2.2	0012.01a1.cda1	Fa0/0																																		
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Layer 2: Datalink	<table><tr><th>Interface</th><th>Line Protocol</th><th>MAC address</th></tr><tr><td>E0/1</td><td>Up</td><td>000c.30e2.e501</td></tr></table> <table><tr><th>Interface</th><th>Line Protocol</th><th>MAC address</th></tr><tr><td>E0/0</td><td>Up</td><td>000c.30e2.e500</td></tr></table>	Interface	Line Protocol	MAC address	E0/1	Up	000c.30e2.e501	Interface	Line Protocol	MAC address	E0/0	Up	000c.30e2.e500																							
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Figure 7. State Model Diagram of router showing for RIP protocol (Maj & Veal, 2007, p. 205)

ECU - State Model Diagrams															
OSI	TCP/IP	Router1 (192.168.10.1)													
Layer 3: Network	Internet	ARP Table													
		Address	Age (min)	Hardware Addr	Interface										
		192.168.10.2	184	0009.b76f.ad61	FastEthernet0/0										
		192.168.10.1	-	0009.b765.2a20	FastEthernet0/0										
		192.168.1.1	-	0009.b765.2a30	Ethernet1/0										
192.168.1.2	0	0001.6c81.61c8	Ethernet1/0												
Routing Table															
		Code	Dest Address	Distance	Metric	Next-hop IP	Entry Age	Interface							
		C	192.168.10.0/24					FastEthernet0/0							
		C	192.168.1.0/24					Ethernet1/0							
		R	192.168.2.0/24	120	1	192.168.10.2	00:00:01	FastEthernet0							
		Interface		IP Address		Interface		IP Address							
		FastEthernet0/0		192.168.10.1/24		Ethernet1/0		192.168.1.1/24							
Layer 2: Datalink	Access	Interface			Line Protocol		MAC Address		Interface			Line Protocol		MAC Address	
		FastEthernet0/0			up		0009.b765.2a20		Ethernet1/0			up		0009.b765.2a30	
Layer 1: Physical	Access	Interface		Line Status		Interface		Line Status							
		FastEthernet0/0		up		Ethernet1/0		up							

Figure 8. first version of SMDs software which using Telnet communication protocol

The network management protocol has been constructed to many standards, such as the simple network management protocol (SNMP). SNMP allows users to retrieve information from network devices, therefore SMDs software should encompass this approach. The development of software in the new approach has been prototyped, but the software is not yet completed. Furthermore, its evaluation in regard to distance learning environments also needs to be done.



Node Detail window showing detailed information for node 192.168.1.1 ("Router1").

Layer 3 Internet:

Interface	MAC	IP	media type
1	00-09-87-6F-AD-20	192.168.1.1	1
1	00-10-06-95-05-F0	192.168.1.2	3
1	00-23-86-35-33-92	192.168.1.6	3
3	00-09-87-6F-AD-21	192.168.10.1	1
3	00-12-01-AE-74-51	192.168.10.2	3

dest	interface	metric	next hop	age	net mask
192.168.1.0	1	0	192.168.1.1	0	255.255.255.0
192.168.2.0	3	1	192.168.10.2	27	255.255.255.0
192.168.10.0	3	0	192.168.10.1	0	255.255.255.0

interface	address
Fa0/0	192.168.1.1
Fa0/1	192.168.10.1

Layer 2 network:

Interface	status	Mac Address	type
Fa0/0	up	00-09-87-6F-AD-20	6
Fa0/1	up	00-09-87-6F-AD-21	6
Eth1/0	down	00-09-87-6F-AD-30	6
Eth1/1	down	00-09-87-6F-AD-31	6
Eth1/2	down	00-09-87-6F-AD-32	6
Eth1/3	down	00-09-87-6F-AD-33	6

Layer 1 line:

Interface	line	status
Fa0/0	up	
Fa0/1	up	

Figure 9. the new prototype of SMDs software which using SNMP protocol

Figure 9 shows the new prototype of SMDs software which encompasses the SNMP approach. The user can navigate to different networking devices; the program can be configured to show the different levels of information.

Section 4.5.1 in CHAPTER 4 will introduce one example of a network management protocol, the simple network management protocol (SNMP), which has been used in the new SMDs prototype.

The value of SMDs in teaching was said to due to their hierarchical structure, which allowed learners to focus on individual levels of internetworking equipment's behaviour. Also, SMDs allowed the learners to exclude other irrelevant information from their focus (Veal, 2003, p. 4).

2.9.2 Possible learning assessment aid of SMDs

There are many way of assessing and measuring students' understanding of their coursework content. Different tools have been proposed for general measurement and there are advantages and disadvantages of using such tools. However, with the current requirement from industry for course providers to develop a new workforce rapidly, assessment processes have only recently become an issue to be addressed.

An approach to measure and categorise students' ability needs to correspond to pedagogical guidelines, such as Bloom's and the SOLO taxonomies. Such frameworks can be used to guide the design of questions for measuring and categorising students into groups (Whalley, et al., 2006). A combination of different taxonomy guidelines provides more accurate results.

Scouller (1997) suggested that practical essays were suitable and the preferable way of measuring the students' ability in order to encourage deeper learning strategies, while multiple choice questions (MCQ) were associated with surface measurement. However, practical examinations that reflect a real life problem but are focused too much on concrete levels may decrease deep learning (Gulikers, Bastiaens, Kirschner, & Kester, 2006). Furthermore MCQs and short answer questions still have great value in practice and can encourage deep learning (Denny, Hamer, Luxton-Reilly, & Purchase, 2008). They can also be useful as a revision tool to help discover lack of knowledge in given areas. However, it might be more appropriate to assess students from a combination of methods.

Assessment tools in distance learning may require different features (Dennen, 2008). In internetworking, distance learning tools such as network simulation tools can be applied for assessment (Frezzo, Behrens, Mislevy, West, & DiCerbo, 2009). Furthermore, SMDs are diagrams that are structured from hierarchical concepts, showing relevant information about networking devices. SMDs may be applied to aid the learning process in internetworking. However, more research is needed in this area.

2.10 Laboratory delivery methods in internetworking education

Since laboratory exercises are crucial components in networking education, there are various methods of delivering laboratory experiences to students. At least three different delivery methods have been mentioned in the literature so far (Ma & Nickerson, 2006, p. 6). This section will describe these delivery techniques, their benefits and drawbacks.

2.10.1 Hands-on laboratory

As in other science disciplines, laboratories involve the setting-up of real equipment and hands-on experiences for the students must be provided by the laboratory facilitators. Network education also encompasses this approach as a traditional way of teaching, particularly for higher educational providers such as computer science schools in universities.

The hands-on laboratory is an important means by which internetworking students are given access to the course contents. It is a traditional form of laboratory which is open for face-to-face communication between students and lecturer(s). The critical factors of the hands-on laboratory are:

1. Direct communication between students and lecturers or tutors
2. Actual hands-on experience with real equipment
3. Fast response times of laboratory equipment.

The laboratory will help the student to gain actual experience that differs from simulation and other types of delivery methods. This is as Sarkar (2006, p. 1) stated, as *“by setting up and configuring actual computer networks, the student gains first-hand experience that cannot be gained through computer simulation and modelling”*. This study also confirms the effectiveness of hands-on experience with superior performances from students who attended hands-on sessions (Sarkar, 2006, p. 290).

Heise (2006) has identified three aspects of the superior features of the hands-on laboratory compared to a simulation laboratory:

1. In learning science, students learning new concepts would be able to connect and transfer their knowledge through the usage of physical equipment.

2. In cognitive science, hands-on laboratories minimise the mapping process between higher abstract concepts and concrete learning, and emphasise longer retention of knowledge.
3. Physical laboratories enhanced the learning experience and introduced real world issues such as equipment failure, which simulation tools cannot entirely imitate.

Heise (2006) stated that the hands-on laboratory helps learning processes by increasing student involvement in learning, by building problem-solving skills, increasing motivation, alerting students to the cost and time involved in providing the laboratory and generally stimulating interest.

Yuan and Zhong (2008) presented their work of facilitating the use of a hands-on face-to-face laboratory by incorporating the usage of open source software. Simulation tools such as Zebra were used to simulate router behaviour on Linux machines. The curriculum used in the study was based on educational theory. The results from the study support the usage of a hands-on laboratory for students as a supplement to theory based lectures.

Cao et al. (2009) also presented their multiple purpose network laboratory design, which tried to cater for usage requirements ranging from basic teaching sessions to graduate research projects. The design incorporated the use of centralised racks, virtual machines, simulation and optimisation software, which minimised space requirements, reduced machine costs and provided a suitable foundation for both learning and researching.

Hands-on learning experiences could also be regarded as important for the workplace. Most students attend university to improve their conditions, whether for their reputation or financial advantages through jobs after gaining a degree (Bui, 2002). Students are expected to be equipped with hands-on experiences in order to be successful in their career (Yuan & Zhong, 2010, p. 257).

However, cost is the major concern in maintaining a hands-on laboratory. Building up a hands-on laboratory does not infer only a lot of equipment costs, but also includes the costly demand for space (Cao, et al., 2009, p.156), instructor time and infrastructure (Ma & Nickerson, 2006, p. 1; Yoo & Hovis, 2004, p. 1). Also, hardware maintenance and technical support are issues of concern. The equipment alone could cost over AUS\$300,000 (Veal, et al., 2005, p. 3).

Stackpole (2008, p. 244) stated four disadvantages of hands-on face-to-face laboratories as following:

1. Cost of providing laboratory space and equipment is high.
2. Availability of physical laboratory is limited and is not fully utilised.
3. Maintenance and upgrading physical hardware is typically slow.
4. The physical laboratories can be only accessed by the local community.

Availability of the laboratories is a factor to be considered as the demand for such facilities might not correspond with the universities' supply, especially during the peak period such as examination time. Moreover, distance learning is also incompatible with the hands-on laboratories (Watt, Walther, & Nowak, 2002). Furthermore, Goldstein (2005) pointed out that teaching internetworking could be difficult as the actual network interconnections would not be visible, and students may have difficulty in conceptualising their structures.

In summary, the advantages and disadvantages of physical hands-on laboratories are presented in Table 5.

Table 5. Advantages and disadvantages of physical hands-on laboratories

Advantages	Disadvantages
<ul style="list-style-type: none"> • Direct communication • Actual experience with real equipment • Actual response time of equipment • Minimise mapping process between concrete and abstract learning • Introduction to real world issue 	<ul style="list-style-type: none"> • Cost of providing laboratory space and equipment • Limited availability • Incur maintenance costs • Hardware needs to be upgraded regularly • Local access only • Not compatible with distance learning • Visualising and conceptualising the real network could be difficult

Therefore, a hands-on laboratory seems to be too expensive for education institutes with limited budgets. This is the reason why other delivery methods, simulations and remote access classrooms, may still play an important role in networking education.

2.10.2 Simulation laboratories

Simulation is the use of technology to imitate physical phenomena by copying their key characteristics. The purpose of simulation could be for gaining understanding of specific phenomena. The significant early use of simulation technology can be referred back to the usage of flight simulators before World War II, in 1928. The use of a flight simulator called “Blue Box” saved aviator lives and millions of dollars (Feisel & Rosa, 2005, p. 121). Nowadays, with advances in computing technology, simulation is more common in the form of simulation software. The introduction of these new technologies in the past two decades has also caused changes to the form of teaching laboratories, particularly in computer networking.

A simulation laboratory in the form of simulation software permits experimentation in virtual environments with virtual equipment. The infrastructure in the simulated laboratory is not real, but simulated on computers (Ma & Nickerson, 2006, p. 6). This form of laboratory offers flexibility so that students may learn independently from limited actual resources.

Basically, the networking laboratory should strengthen the knowledge that has been taught in class, offer additional learning opportunities for students and provide an environment in which students can learn independently with less supervision. Therefore, the characteristics of a simulation laboratory should include the following properties (Guo, Xiang, & Wang, 2007, p. 217).

- Simulation software should support a wide range of networking technologies. This should include a variety of equipment.
- The simulation tools should be easy to use without students having to experience a complicated learning curve.
- Cost of simulation software should be low or free.
- The simulation software should have a high degree of accuracy and performance so that experimental results are close to those achieved on actual equipment. The software should also offer a short response time.

2.10.3 Example of network simulation tools

2.10.3.1 Cisco Packet Tracer

Cisco's Packet Tracer is an example of network simulation software that has been used in the Cisco Network Academy Program (CNAP). It helps students and instructors by simplifying the teaching of complex technical concepts. Packet Tracer replaces physical equipment and allows students to build a network with an unlimited number of devices (Cisco, n.d.-a). Packet Tracer also allows students to build simulations across networks such that student can combine Packet Tracer simulations together on different machines. However, at this stage Packet Tracer can only be connected with other Packet Tracer programs that are running on different machines and cannot connect to actual physical devices (Makasiranondh, Maj, & Veal, 2010b). An article written by the author of this thesis, discussing Packet Tracer in more detail, can be found in the Appendix F.4.

The simulation was designed as a teaching tool by displaying visual graphics of the interconnection process and the transmission/receiving of packets in the virtual network Figure 10.



Figure 10. Cisco's Packet Tracer

Packet Tracer had the major advantage of an unlimited number of simulated devices when compared with the limited number of devices and the budgetary concerns associated with a physical hands-on laboratory.

2.10.3.2 OPNET

OPNET (OPNET Technologies Inc., n.d.) is another network simulator that has been used widely. It has a large user community and is freely available for academic use (Guo, et al., 2007, p. 218). OPNET is a set of leading software products. There are two software products that have been used popularly in networking education, OPNET IT Guru and OPNET Modeler. OPNET IT Guru is just a simulation software, whereas OPNET Modeler has the additional functionality of creating new system components (Hnatyshin & Lobo, 2008, p. 242). OPNET IT Guru has an academic edition which is available free of charge if used for teaching purposes (Guo, et al., 2007, p. 218). Figure 11 shows the network-level modelling screen of OPNET simulation software.

OPNET is mainly used for analysing the performance of previously designed systems. For example, it can give a simulated result of the expansion of the network from Figure 11 to Figure 12 by capturing specific statistical data. Figure 13 shows the comparison between two captured results, when introducing a second network to the original topology.



Figure 11. Network-level modelling of OPNET



Figure 12. Expansion of the original design from Figure 11



Figure 13. Simulated performance evaluation result from OPNET

Unlike Packet Tracer, OPNET developed for handling different requirements. The ability to visualised network traffic in an animation graphic, found in Packet Tracer, was not available in OPNET. Also OPNET uses were not emphasised on network devices configuration as in Packet Tracer. However, Packet Tracer did not offer a tool for capturing and evaluating network performance.

2.10.3.3 Emulation software and other platforms

Another way of doing an internetworking experiment is to use emulation software. In this context, emulation means the replacement system that can perform in exactly the same way as the original system but may respond at a slower speed (Dictionary.com, 2003). An emulator offers a more realistic experience in the sense that an experiment need not be conducted entirely as a simulation. However, simulation and emulation may be used in various combinations to conduct experiments in virtual environments. A software-based simulator, such as GNS3 (GNS3), is similar to other simulation software, but uses the actual response from an emulated router operating system (Figure 14). A disadvantage of GNS3 is that students would need to obtain their own Internetwork Operating System (IOS) images to run on their PCs. Furthermore GNS can cause problems by overloading some CPUs with more than a few devices being emulated.



Figure 14. GNS3

Furthermore, a hardware-based emulator, such as Zebra (GNU Zebra, n.d.), is open source software emulating the function of the router on a normal personal computer (PC). Zebra has been used to create a laboratory environment by Yoo and Hovis (2004). Yuan and Zhong (2008) also incorporated Zebra as open source software in their open laboratory to be used to build hands-on skills for students. Chengcheng (2009) also provided a networking laboratory equipment by using emulated tools. Their usage of such a facility illustrates the grey area between an emulation laboratory and a hands-on face-to-face laboratory; they provided the facility as a supplement for face-to-face theory-based classroom by using emulated tools rather than the real equipment.

Stewart, Humphries and Andel (2009) presented a full scale virtualisation laboratory framework for use with network security courses. Their paper reported their design, from the smallest building block to a full scale machine consisted of a virtual machine (emulation) of servers, a virtualisation manager, and a virtual network connection between virtual servers. This building block was designed in a scalable way, in which each block could be interconnected to other building blocks through physical connections to form a more complex simulated environment.

An open-sourced platform of simulation-emulation tools was also observed. Clack provided an example of a platform that was available for free download or online (Stanford University, 2010). Users could control, and configure a virtual router via web access (Daniel Wendlandt, 2005). Figure 15 shows the console interface of Clack that allowed users to configure routers using CLI commands. Clack simulated router's

live traffic and allowed users to visualise the internal process of the router (Dan Wendlandt, et al., 2006). Figure 16 shows Clack's visualisation of router internal process.



Figure 15. Clack simulation's console screen



Figure 16. Clack's router visualisation

In summary, the examples from the literature showed a variety of simulation and emulation tools that are available. These tools' designs were varied for performance evaluation, equipment virtualisation, enhancing network visualisation and teaching purposes. The application of these tools surely incurred advantages and disadvantages. In order to incorporate efficiently such tools within internetworking education, educators may need to be aware of both perspectives.

2.10.4 Advantages and disadvantages of simulation-based laboratories

The main advantage of using a simulation-based laboratory is its low cost. Guo et al. (2007, p. 1) state below:

The simulation approach is the most cost effective and highly useful because it provides a virtual environment for an assortment of desirable features such as modeling a network based on specific criteria and analyzing its performance under different scenarios with no cost.

A simulation-based laboratory provides a practical approach to distance education, especially when independent learning practice needs to be provided. Studies show positive results when simulation software is used by students. It may even help by encouraging and engaging the student in the learning exercises they must complete (Goldstein, et al., 2005; Hnatyshin & Lobo, 2008).

In some cases simulation software can be preferable to real networks, especially when measuring the performance of the network. *“Even if a network is available for measurement, simulation may still be preferred because it allows the evaluation of performance under a wide variety of workload and network conditions* (Hassan, Fahmy, Wu, & Aziz, 2004).” Simulations also offer mobile students with the ability to practice network testing and configuration anywhere they can take their laptops. It is more difficult to move real routers and switches from place to place.

Other aspects when considering simulation in internetworking may be related to *performance simulation* such as that described in (Hassan, et al., 2004). In this case, simulators are mainly used to pursue the purpose of tracking and measuring the performance of the computer network. This shows another application of simulation software. However, such tools may be more highly related to network performance research and may not allow users to learn basic concepts such as maintaining and configuring networks (Gerdes & Tilley, 2007, p. 77). This research study is tied to the

simulation tools that imitate the behaviour of internetworking equipment in the real world for the purposes of teaching and training only.

The enhancement of network visualisation in simulation tools was another strong advantage. Internetworking students using physical equipment may struggle to see the overall picture of their connected networks, hence it may be hard for them to learn networking concepts (Goldstein, et al., 2005, p. 223). The operation of simulation tools allows the display of a network's connectivity in diagrams and hence enhances students' understanding of abstract concepts (Stewart, et al., 2009; Dan Wendlandt, et al., 2006).

However, regardless of simulation-based laboratories' advantages, using them may involve some disadvantages.

- Simulation software incurs an extra learning curve for students.
- There is a disconnection from reality.
- Using simulation tools as a replacement for actual equipment may not be recommended.
- Development cost of simulated tools may not necessarily be lower than that of actual devices.

Firstly, using simulation software may require students to spend time to learn how to use the software. Some software may necessitate a steep learning curve and more time will be taken before each student has become familiar with its use. In some cases, academics need to dedicate one session explicitly for students to learn only the usage of the software without beginning any networking experimentation (Hnatyshin & Lobo, 2008, p. 243). Ma and Nickerson (2006, p. 6) state "*the theory of situated learning would suggest that what students learn from simulations is primarily how to run simulations*".

Secondly, the excessive usage of simulation software may distract students from seeing the connection between the real and virtual worlds (Magin & Kanapathipillai, 2000).

Thirdly, the usage of simulation tools as a replacement for actual equipment may not be recommended by teaching institutions. As Cisco stated:

Packet Tracer [simulation tool] is not a replacement for lab equipment. Networking Academy recommends the use of physical equipment for hands-on learning. This is a key differentiator relative to other programs. Packet Tracer [simulated] activities are designed to provide additional learning opportunities to complement the hands-on lab experience (Cisco, 2007, p. 4).

Finally, although the usage cost of simulation software is low when compared to real equipment, the cost of developing such software, to capture every realistic detail, may not necessarily follow the same lower trend (Papathanassiou, Oster, & Baier, 1999).

The advantages and disadvantages of simulation-based laboratories are summarised in Table 6.

Table 6. Advantages and disadvantages of simulation-based laboratories

Advantages	Disadvantages
<ul style="list-style-type: none"> • Cost effective in terms of virtualisation of equipment • Simulated equipment has high availability • Distance learning is supported • Convenience, mobile • Advanced network and performance evaluation can be easily available through software • Network visualisation is highly enhanced in simulation software • Simulation tools encourage students to do free trial and error 	<ul style="list-style-type: none"> • Developing cost of tools may be expensive, hence obtaining the tools may incur various costs • Usage of simulation tools requires the extra learning curve of using the tools • Students may experience a disconnection from reality • Simulation results may differ from actual equipment responses • Not recommended to be used as a sole teaching methods

Applying a simulated laboratory in networking education should also be considered from a learning perspective. Applying such a laboratory directly for beginners may introduce later difficulties for some students. The educators should consider the advantages and disadvantages of adopting simulation tools and compare them with other modes of laboratory delivery.

2.10.5 Remote access laboratories

Another mode of delivery of the internetworking laboratory is through remote access. A remote access laboratory can be used with distance learning. Instead of obtaining experimental results purely from the simulation software or physical equipment, the remote laboratory uses the real response from actual equipment, as in the physical

hands-on laboratory. However, the distance between the experiment and the experimenter is the factor that makes the remote and hands-on laboratories different. In other words, the remote laboratory controls the hands-on equipment which is detached from the experimenter by geographical distance.

Figure 17 shows the essential architecture of the remote access laboratory (Nuangjamnong, Maj, & Veal, 2008, p. 6). In general, students may remotely connect to networking devices in the laboratory via the Internet. The access server will allow the students to shut down any devices while the controlled connection is still maintained.



Figure 17. General remote access laboratory architecture (Nuangjamnong, et al., 2008, p. 6)

The need for hands-on laboratories in networking education is well known (Sloan, 2002, p. 1). However, there are some difficulties, as mentioned earlier in physical and simulation-based laboratories, especially in the following areas (Aravena & Ramos, 2009, p. 3):

- limited availability of the laboratories (Stiubiener, et al., 2006, p. 1);
- unsuitability for distance learning; and
- the requirement to transfer the students from the classroom to the laboratory location.

Simulation laboratories do not offer realistic experiences to students. Remote access laboratories may compensate for this disadvantage, by providing realistic experiences while increasing the availability of the laboratories.

Requirements of the ideal remote laboratory are as follow (Pullen & Chen, 2008):

- Support audio-graphic contents, even with the slow speed connection of a modem
- Web-based access and software to manage the user login and logout
- Support multiple platforms of computer operating systems

The main advantage of using a remote access laboratory is its availability. The remote laboratory allows students to access the equipment at any time from anywhere. It reduces problems of scheduling laboratory usage (Stiubiener, et al., 2006, p. 1). Although the ideal pedagogical and availability solution would be having a teacher and a real laboratory available 24 hours a day, such a situation is not feasible and remote laboratories are an adequate substitute (Sebastian, Garcia, & Sanchez, 2003).

Furthermore, theoretical lessons and practical experiments can be carried out in the same classroom by remote access laboratories (Aravena & Ramos, 2009, p. 4). This may also create an opportunity for handicapped students to access the laboratory equipment as the remote laboratory requires less safety precautions to be taken than the physical laboratory (Armstrong & Murray, 2007; Murray & Armstrong, 2009). By increasing the availability, the cost effectiveness ratio of building and maintaining the equipment was also increased (Nuangjamnong, et al., 2008).

Another advantage of the remote laboratory is that it allows collaborative usage between universities (Jakab, Janitor, & Nagy, 2009), which helps to reduce costs and allow the network equipment to be centrally managed.

In summary, the advantages of remote access laboratories are:

- High availability, students can have access to the laboratory at their own convenience, time and place.
- Provide more access to the laboratory; hence reducing conflicts within the scheduled usage.
- When using a remote access laboratory, the theoretical and practical classes could be conducted in the same place.

- Provide handicapped people with access to the laboratories
- Cost effective usage of equipment by providing more access
- Promote collaboration between universities as shared resources

2.10.5.1 Issues of using remote access laboratory

However, there are some concerns about using a remote access laboratory. There are three disadvantages of using remote access laboratory, which are:

- Security concerns of using a remote laboratory
- Physical interaction and wiring changes of physical network
- Pedagogical concerns of using remote laboratory

Firstly, there are security concerns. A remote login facility should provide the ability to screen and allow only authorised people to use and reconfigure the laboratory resources (Sivakumar & Robertson, 2004, p. 179). Sloan (2002, p. 2) states “*you cannot allow just anyone on the Internet to reconfigure your equipment. Nor will you want your laboratory to become a staging ground for attack across the Internet*”.

Secondly, the disadvantage of remote access laboratories was their lack of interaction with physical equipment. The lack of physical access prevents remote users from doing any structural changes, such as re-cabling the network setup. In comparison, students of physical face-to-face laboratory may have immediate chances to restructure their own computer networks, by reconnecting, re-designing and re-building them.

Wiring may need to be changed in order to adjust the equipment to suit different experiments (Sivakumar & Robertson, 2004, p. 187). Changing wire connections cannot be done easily, as the actual experimenters are disconnected from the laboratory by distance.

The physical topology of remote access laboratories is rather fixed or can be modified only by request. Some remote access facilities may choose to have a fixed cabling topology and allow the students to access different slots of equipment as pods (Prieto-Blazquez, Arnedo-Moreno, & Herrera-Joancomarti, 2008). Another solution may be to

choose to provide the facility to adjust the logical connectivity between equipment (Yoo & Hovis, 2004).

The fixed cabling solution may not be suitable to build with a low budget and it loses the flexibility to reuse the equipment. On the other hand, the logical adjustable connectivity solution may create more pedagogical issues, as every piece of equipment is physically interconnected. As Nakagawa, Suda, Ukigai and Miida (2003, p. 18) stated *“it seems the virtual machines connectivity makes it difficult for students to understand each connection because the virtual machines are connected to each other by invisible network cables.”*

Both fixed cabling and logical connectivity failed to provide any physical layer interaction, which is an important factor for student learning. Novice students, especially, who may not have seen any internetworking equipment, could find it difficult to distinguish between logical and physical concepts. Remote laboratories' facilities should provide an acceptable degree of physical interaction.

Lastly, the pedagogical concerns of using a remote laboratory are also important. Because not all type of experiments can be done remotely, finding the appropriate set of activities that can be used with a remote laboratory is a major problem. The laboratory should provide “authentic activities” while overcoming, as far as possible, the limitations due to remoteness (Sivakumar & Robertson, 2004; Sloan, 2002, p. 220). In this context, authentic activities mean the activities that are similar to, or help students to encounter, the real problems in working environments (Guzdial & Weingarten, 1995, p. 6).

Furthermore, the extensive use of the Command Line Interface (CLI) alone in the remote access laboratory extended the pedagogical issues (Armstrong & Murray, 2007; Murray & Armstrong, 2009). CLI was developed for using with professional networking standards and does not have sufficient pedagogical guidance to be solely used with novice students.

In summary, the advantages and disadvantages of the simulation-based laboratory can be summarised as in Table 7.

Table 7. Advantages and disadvantages of remote access laboratories

Advantages	Disadvantages
<ul style="list-style-type: none">• High availability• Provide more access to laboratory• Use responses from actual equipment, not simulated results• Theoretical and practical classes could be conducted at the same place• Provide handicapped access• Cost effective by providing more accessibility• Promote collaboration between universities• Support distance learning	<ul style="list-style-type: none">• Security risk of online identification• Lower physical interaction, compared with face-to-face mode• Issue of re-structuring the network in practice, re-wiring issues• Pedagogical concerns about remote access tools• Distance between users and equipment, disconnection

Therefore, the use of remote networking laboratories should facilitate completion of suitable activities. Institutions should also supply the right tools to compensate for the major burden of communications over long distances. Reliable audio and visual communication with instructors in real time can also be useful when students are required to access remote laboratories.

2.10.5.2 Remote laboratories in other engineering education disciplines

Machotka et al. (2010) presented a remote laboratory for microelectronic classes, called NetLab. This facility has been used collaboratively by the University of South Australia (UniSA) and offshore participants from Singapore, Sri Lanka, Sweden and Portugal. Nafalski et al. (2010) discussed the pilot survey results from the group of students. The feedback from students points out the positive aspects of using such a facility.

The Virtual Instrument System in Reality (VISIR) is a collaborative project between many universities to create a central environment between institutions to share their local laboratory facilities (Gustavsson, Zackrisson, Håkansson, Claesson, & Lagö, 2007). It acts as an open platform which provides open source tools to allow the members to develop their own shared facility with other universities. Although the project is broad and is not focused only on microelectronic laboratories, the origin of this initiative is based from microelectronic classes. The current members of this collaboration consortium seem to be limited to microelectronic equipment providers.

Sebastian, Garcia and Sanchez (2002), presented another application of remote laboratories in control engineering classes. The same authors, Sebastian et al. (2003), also presented the usage of a remote laboratory in image processing classes. The students can remotely capture an image of an object by adjusting the camera to prepare an input image for further processing steps. Then they have an opportunity to process the acquired image by using a combination of basic algorithms which has been studied in class. Pullen and Chen (2008) showed another example of a remote laboratory for computer graphics classes, which require the sharing of high resolution applications between students.

Melkonyan, Akopian and Chen (2009) studied the usage of a remotely accessible laboratory with telecommunications engineering students. The results showed that the students would like to participate in the remote laboratory and that they perceived the potential of the availability of their remote access laboratory. In Thailand, Lertkulvanich, Buranajant and Sambunsukho (2008) used a remote access laboratory in a hazardous course that concerned the students' health-related risks of working with radio-active materials.

In summary, these studies showed various applications of remote access laboratories in different courses. They showed the possibility of applying such laboratories to internetworking education and demonstrated some advantages. For example, the incentives for conducting the cooperative projects between universities were emphasised (Gustavsson, et al., 2007; Machotka, et al., 2010; Nafalski, et al., 2010). They showed the possibility of providing a high resolution graphic in the remote session (Pullen & Chen, 2008; Sebastian, et al., 2003). The application of such a laboratory could benefit the learning activities that related to students' safety concerns (Lertkulvanich, et al., 2008). Finally, the perception of students was positive toward using a remote laboratory in their classes (Melkonyan, et al., 2009). The next section discusses further applications of remote access laboratories, specifically in the internetworking field.

2.10.6 Examples of remote networking laboratories

The examples of remote networking laboratories are various. Prieto-Blazquez, Arnedo-Moreno and Herrera-Joancomarti (2008) have used a remote laboratory as one component of a virtual learning environment (VLE). They used a commercial tool,

called NETLAB+ (Network Development Group, n.d.). The implementation of the laboratory addressed security issues by providing a management facility for controlling users. However, the cost concern of using a commercial service such as NETLAB+ may be raised.

Other examples of fixed wired in-house laboratory are found in the works of Armstrong and Murray (2007; Murray & Armstrong, 2009), who used university-owned equipment for building a remote access facility and avoided further demands for fees by not using a commercial service. Although the facility is inferior to the NETLAB+, it was another cost effective solution to provide access to students.

Usually in a remote laboratory arrangement, the equipment was fixed in the form of “pods” or “bundles” for each set of experiments. Figure 18 shows an example of available experiment “pods” which are dedicated remote equipment slots for students to login and use. Therefore the wiring is already preconfigured and cannot be changed.



Figure 18. NETLAB+ available exercise screen.

This fixed wiring laboratory is a trade-off between simplification and reusability of the laboratory setup. However, the cost of implementation is another concern as it is likely to be higher when providing a fixed dedicated wiring laboratory.

Chengcheng (2009) described a remote facility that blurs the boundary between simulated and real laboratories. By providing remote access to all simulated equipment, he shows a next generation of internetworking laboratories that efficiently use the limited resources which are locally available. Furthermore, Yoo and Hovis (2004) present a fully automated remote laboratory to which students may gain access at any time. The laboratory uses low cost router-emulated PCs. This laboratory is an example of a situation where the wiring does not need to be changed as different network topologies can be set virtually through the reconfiguration of switches. However, pedagogical concerns about laboratory setup can become an issue as students may be confused about the physical interconnection of all equipment.

Stiubiener et al. (2006) presented a framework for developing networking laboratories for distance learning and the remote laboratory is one of the most important components. He describes using a set of tools to capture an image of the physical connections of the equipment. Sivakumar and Robertson (2004) also presents a web-based remote networking laboratory. It addresses cabling issues by maintaining interactive communications between remote students and the laboratory's facilitators.

Armstrong and Murray (2007; Murray & Armstrong, 2009) offer another example of remote laboratory that has been used to support learning processes for handicapped students. Aravena and Ramos (2009) have evaluated the usage of a remote laboratory and the feedback from students is positive.

Stackpole (2008) showed the evaluation result of his development of a remote facility to teach networking, security and systems administration subjects. The main reason for him to start using a remote facility was the high maintenance cost of a physical laboratory, low availability of access for students, combined with maintenance and upgradeability issues of physical equipment. Using the remote facility provided an ability to cooperate between different institutions to share expensive equipment.

Jakab, Janitor and Nagy (2009) presented their work on the remote access laboratory which allows users to connect to different devices through a single user interface. Also, the users can remotely operate the power cycle of the devices. This remote facility uses

its own devices to handle controlled signals and power supplies. The software component running on the central server of every lab kit provides the ability to control devices without being directly connected to them. This article also mentions collaboration between universities in using this virtual laboratory facility.

Stretch (2008) provided a community remote access laboratory that was available freely online, called Packet Life. In his work, he used a fixed wired laboratory structure, which had fewer maintenance concerns but limited usability. Figure 19 shows the physical equipment and logical topology of the Packet Life community laboratory. Users need to register on the website and book a time slot for using the equipment.



Figure 19 Packet Life community remote access laboratory (Stretch, 2008)

In conclusion, remote laboratories have been used widely as one significant means of distance learning. The usage of the remote networking laboratory has emphasised conceptual understanding but focused less on designing skills (Ma & Nickerson, 2006, p. 9). In comparison to other types of laboratory, the remote access laboratory offered better access and availability but less physical interaction with the actual equipment. Figure 20 shows the characteristic of all three types of laboratory. Hands-on laboratories provide the highest degree of realistic experience while simulation laboratories feature higher portability.

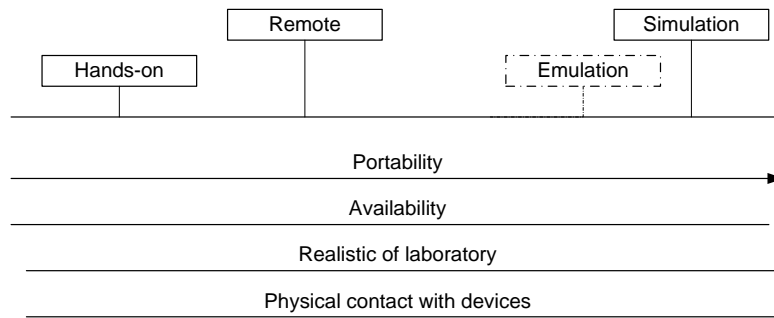


Figure 20. Characteristics of three laboratory types

Because of the nature of remote laboratories, the students are disconnected from the experimental equipment by distance. The students may be confused by the less physical visual representation of the experimental setup. The literature examined so far regarded the provision of an internetworking remote access laboratory to be limited to a text-based command line interface connection (Armstrong & Murray, 2007; Chengcheng, 2009; Ma & Nickerson, 2006; Murray & Armstrong, 2009; Prieto-Blazquez, et al., 2008; Stackpole, 2008; Stiubiener, et al., 2006; Stretch, 2008; Yoo & Hovis, 2004).

This identifies the need for pedagogical tools which may support the conceptual understanding of students while also strengthening their design skills by virtually displaying the overview of the laboratory. The author of this thesis, Makasiranondh, Maj and Veal (2010c), explained their preliminary work on deploying pedagogical tools such as SMDs in a remote laboratory environment. These tools may compensate for the pedagogical disadvantages of remote laboratories and may bring users an experience closer to the usage of actual hands-on laboratories. However, more research in this area is needed.

2.11 Related literature about the evaluation of internetworking as distance learning

Evaluation of any distance learning experience could be undertaken by considering different aspects. One of the examples might be to listen to the responses from the participants. However, the collection method of these participants' reactions sometimes is seen as unreliable or using invalid indicators to assess the program objectives (Clark, 1994). Therefore, every evaluation process should have a tool to measure the success of the program in meeting its objectives alongside the participants' feedback.

The objective can be divided into at least two different aspects, namely an evaluation of the delivery medium and an evaluation of instruction from the point of view of instructional theory. The main focus from instructional theory should be concerned with (1) changes in students' learning, (2) values that have been added to both students and teachers, (3) motivation of the students and (4) the application of the knowledge to reality outside the classroom. On the other hand, the focus on the delivery medium are the questions that concern (1) increasing the rate of student access to classrooms, (2) utilisation of the resources and (3) reliability of the media used in the classroom.

Nakagawa et al. (2003) evaluated their own laboratory which used VMware to teach the students to administer application servers (DNS, Mail, www) on the network. The result was satisfactory according to the feedback provided by students involved in the lab. This was shown from a questionnaire result that most of the students agreed that the laboratory was easy to follow. They also provided hierarchical concepts by organising the laboratory into three different levels. However, there was a concern about using virtual machines, as they found that virtual reality of these machines created some difficulty to students' understanding process.

Martínez-Torres et al. (2008) presented a generic statistical model for measuring the technological acceptance of the new e-learning technological tools of the students. The model based on Technological Acceptance Model (TAM). The main component of TAM consisted of three measurable features, namely:

- the intention of use,
- the ease of use, and
- usefulness.

Martínez-Torres et al. (2008) developed other features to measure this technological acceptance as well in conjunction with the original 3 features, in total 15 features. They presented the new acceptance model drawn from their 15 features. The conclusion was that the ease of use feature seems to have less effect on the students' perceptions of the adoption of the new technological learning tools.

2.12 Conclusions

The study of computer networks can be challenging. Students have to learn everything concerned with theoretical and technical computer networking concepts. When given the opportunity, diagrammatic tools or models can be used to enhance students' understanding and replace some aspects of internetworking contents. This is a great opportunity to investigate ways to overcome the difficulties of computer networking course content.

Computer and internetworking technologies are complex and considerable understanding is required to design and operate them. Diagrams and models based on abstraction are broadly applied in the curriculum to assist in providing that understanding (Kohli, et al., 2005, p. 4). A similar research study by Davis, Ransbottom and Hamilton (1998) supported the idea that internetworking technology adjusts multiple, diverse, underlying hardware by providing the means of interconnecting heterogeneous networks. Hence, there are various methods to teach computer networking. With internetworking technologies, they are taught in the modern computer networking curriculum. The Cisco Certified Networking Associate (CCNA) has evolved to support the educational theory and conceptual modules in computer networking courses (Maj & Kohli, 2004).

Naps et al. (2002) affirmed that visualisation technology can be used to illustrate various concepts in computer science graphically. One of the most significant current diagrammatic tools is the State Model Diagram (SMD) which is used to extract information from internetworking technologies. The diagrams are designed to provide IT students with a better conceptual model which takes full advantage of their understanding of computer networking concepts (Maj, et al., 2004). Maj et al. (2005) emphasised that the advantage of the SMDs is to bring the physical network into logical networking concepts, and it also brings the logical networking concept to the physical network. Thus, the SMDs offer multiple views, and provide both hierarchical top-down and bottom-up decomposition which cover technical detail in the theory of computer networking.

Meanwhile, a number of sophisticated network simulators exist and can be used to introduce basic concepts such as communications protocols, routing, bridging and error handling, especially in distant or virtual learning environments. These powerful tools may impose steep learning curves but are excellent for doing in-depth evaluations or

comparing algorithms quantitatively (Carniani & Davoli, 2001). Maj and Veal (2000) admitted that a simulation tool is a preferred approach; nevertheless, students often do not see the whole picture. It is difficult to provide a suitable pedagogical framework which addresses this problem by means of simulation. Also, remote lectures have been used widely and the evaluations show no significant difference from face-to-face classrooms (Sivakumar & Robertson, 2004, p. 182). However, research shows that teaching in these modes also needs to consider pedagogical problems (Nuangjamnong, 2009). These drawbacks identify the need for improvement of distant networking curricula by integrating models, especially SMDs, within them. Evaluations of such integration also need to be done.

Furthermore, graduates of internetworking courses not only needed their technical skills to be fully developed but also required them to be equipped with soft skills or non-technical skills (Bleek, et al., 2005, p. 8; Tucker, 1991, p. 72). The development of such skills needed to be emphasised on the universities' curricula. However, the beliefs of students perceiving those skills also need to be studied. Especially when conducting internetworking courses online, the teaching of soft skills may need to be different than face-to-face mode. Further research in these areas is needed.

CHAPTER 3 RESEARCH PROCESSES

3.1 Introduction to the research framework

This study considered two separate aspects of the overall research topic of internetworking education. Figure 21 represents the framework of the research process used in this study. As is shown, the research included literature reviews, design of the learning environment, developing data collection tools, data collection, data analysis and conclusions.

The research process began from the research questions (Section 1.5). The first aspect of the research was about the introduction of a remote access internetworking laboratory to Thailand. Methods employed for this aspect included extra experimentation on the construction of a laboratory-based learning environment to suit remote Thai students. The construction of this learning environment will be discussed in CHAPTER 4. Learning materials that were suitable for a relatively short experimental time, compared to the regular 14-weeks' course, also needed to be simplified.

Secondly, the research studied non-technical skills building in internetworking education. This research focused on non-technical skills or soft skills that are currently being taught and encouraged in the internetworking curriculum.

Both areas of this research needed well-developed data collection tools. However, the data collection tools for the two areas were different. In general, both data collection tools were designed using close-ended and open-ended survey questions, interview questions and observation. Data collection tools will be discussed further in section 3.5 below.

Due to the different requirements of each aspect, the research participants and research methods used in both studies were slightly different. More discussion about research participants and selected research methods will be presented in section 3.4 below.

3.2 Research study framework

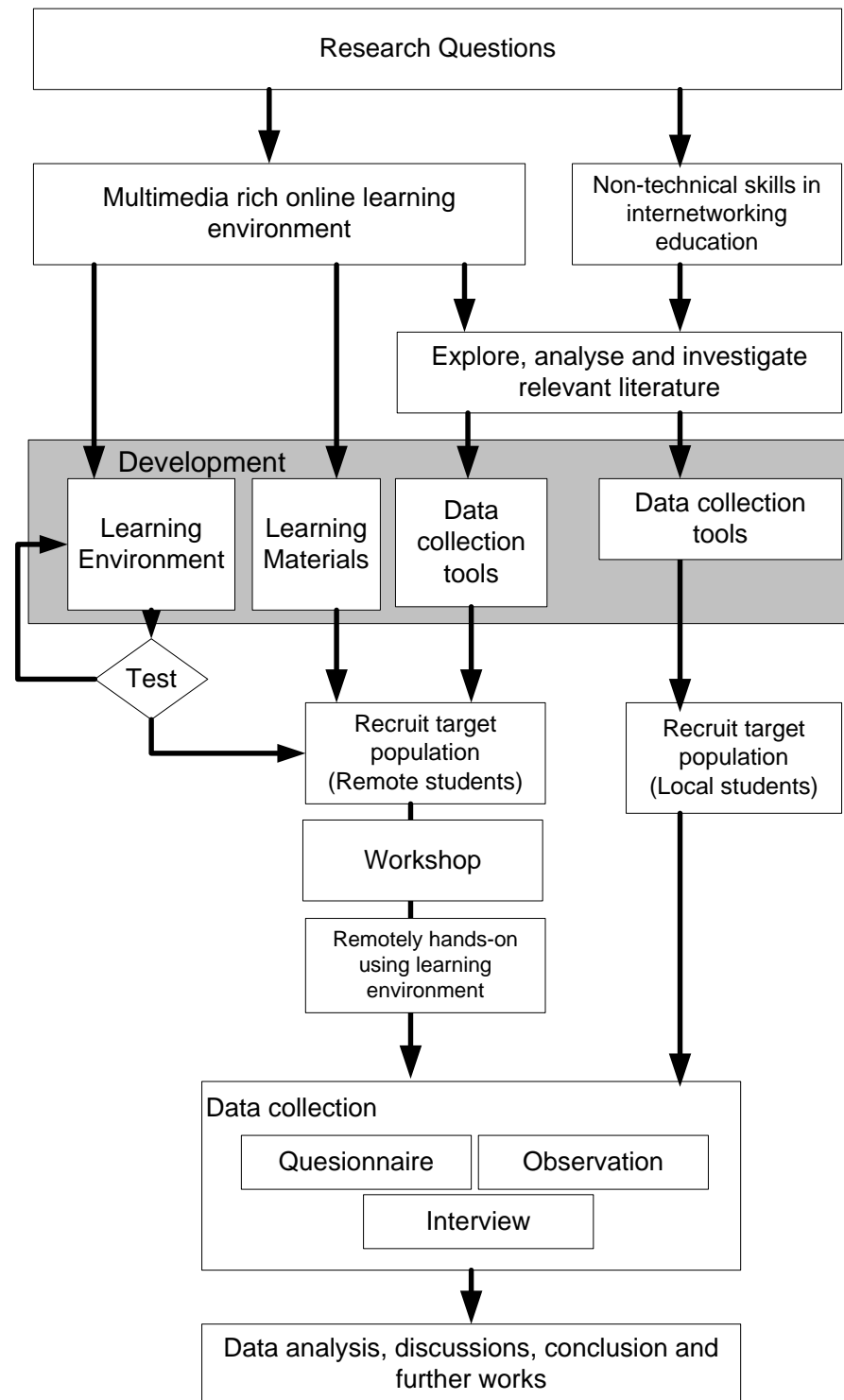


Figure 21. Research study framework

Moreover, the participants' recruitment processes for the two areas of research were not identical, due to the different target populations and requirements. Participants in the rich media learning environment research were asked to attend a two hour workshop

which included time to do a hands-on exercise. On the other hand, the participants in the research about non-technical skills were only asked to express their opinions through a questionnaire.

3.3 Selection of Research Methods

This section will discuss the process of selecting research methods for conducting this research. It will briefly describe qualitative and quantitative research and the way in which these paradigms have been unified to construct a mixed method. An explanation of why the researcher chose to employ a mixed method may be found below.

3.3.1 *Qualitative research*

Qualitative research methods aim to contribute to a complete picture of a situation via the collection of qualitative data. For example, the analysis of narrative data may be used to form a new theory or hypothesis. Often, limited qualitative data could show tentative trends which then may be further investigated on a larger scale.

Qualitative research methods are a major component of this study. According to Johnson and Onwuegbuzie (2004), they provide the following advantages that were appropriate for this research project:

- Suitable for studying a small number of cases in detail
- They can be used to describe a complex phenomena broadly, without losing detail by an overly intense focus on any particular proof of theory or hypothesis (Creamer, 2011)
- Preliminary qualitative research methods may be used to draw a tentative explanation of a phenomenon
- Qualitative researchers may be flexible enough to adjust to changes occurring during the conduct of the study

However, adopting qualitative research methods may not allow the researcher to avoid the following disadvantages:

- The results of using qualitative research may easily influenced or biased by the researchers' opinions

- Generally, obtaining qualitative research data may be more time-consuming
- Also, analysing its data could take more time as qualitative data may be extensive (Onwuegbuzie & Dickinson, 2008, p.207)
- The conclusions drawn from qualitative analysis may be very limited because of researchers' inability to generalise.

3.3.2 *Quantitative research*

In comparison with qualitative methods, quantitative research emphasises the measurement of phenomena through variables. Quantitative research focuses on measurable data and the use of statistical approaches to data analysis. Quantitative research may thus be used to prove or confirm existing theories or hypotheses which had been generated before the research is conducted.

A quantitative approach offers the following benefits:

- The research findings may be generalised, given that the data may be collected through various samples and/or populations
- Quantitative data collection can be relatively quick
- Less time may be spent on data analysis (Johnson & Onwuegbuzie, 2004, p. 19)
- It may have a higher credibility and be less subject to researcher bias.

In contrast, a quantitative approach may be limited, due to the following issues:

- The researcher's theories or assumptions may not be applicable to the understanding of local populations. Hence it may become necessary for the study design to be changed. Such changes may cause the study to be revised entirely (Creswell & Clark, 2011; Driscoll, Appiah-Yeboah, Salib, & Rupert, 2007).
- Quantitative methods focus on the occurrence of narrowly-defined phenomena. While aiming to confirm existing theories or hypotheses, researchers may overlook important findings that were not addressed by the original research questions (Johnson & Onwuegbuzie, 2004).

- They require a sufficiently large sample size to represent the total population before it is possible to generalise from the findings. Conclusions drawn from small or non-representative samples may not be able to show even tentative trends.

3.3.3 *Mixed methods*

Creswell and Clark (cited in Creamer, 2011, p.1) defined mixed methods research as the class of research where researchers blend qualitative and quantitative research techniques in a single study. The unified research approaches offered by mixed methods research compensate for the disadvantages of choosing purely quantitative or qualitative methods. Mixed methods benefit from the advantages of both qualitative and quantitative methods (Johnson & Onwuegbuzie, 2004).

In general, the benefits of employing mixed methods are:

- They combine qualitative and quantitative research strengths
- Mixed methods may be used to generate theory as well as its confirmation (Creamer, 2011; Driscoll, et al., 2007)
- Answers may be found for a broader range of research questions
- It is less likely that significant findings will be overlooked, because the focus of the research is wider
- They can be used to increase an ability to generalise the results

However, drawbacks of using mixed methods are:

- Research methods become more complicated
- Researchers that are familiar with both qualitative and quantitative aspects are needed
- Research may take more time and resources (Driscoll, et al., 2007)

3.3.4 Summary of methods

In conclusion, the three approaches to research discussed above may be summarised (Table 8).

3.3.4.1 Concurrent and sequential approaches

According to Driscoll et al. (2007), mixed methods can be employed by at least two data collection approaches, concurrent and sequential. Creswell (2009, p.15) mentioned that researchers used concurrent techniques, collecting data in both quantitative and qualitative forms at the same time. Using concurrent techniques may offer the advantage of describing complicated and/or inconsistent responses (Driscoll, et al., 2007, p.21).

On the other hand, sequential techniques involve two or more phases of the data collection process, which could be started from an exploration of qualitative factors and a confirmation by quantitative methods, or vice versa. Sequential techniques are iterative approaches during which data from one phase refines the data collection of the next phase (Driscoll, et al., 2007).

In this study, the distance between researcher and the participants created an obstacle to adopting sequential approaches. Online data collection tools separated the researcher from any identification of the participants. If the researcher had chosen sequential approaches, the researcher would have needed specific participants' identification to be able to create any connection between different phases.

Even though part of the recruitment process was to contact teaching staff of Thailand's universities, indirect contact with participants via their universities' authorities may create wrong perceptions and distort participants' feedback. Furthermore, because the role of this research was to compare the situation of internetworking education in Thailand and Australia, there was a danger that the unequal positions of teachers and students may have distorted the quality of the data which was to be collected. The researcher adopted anonymous data collection tools in the attempt to avoid any inequalities and possible conflict of interest issues.

Table 8. Summary of research methods discussion

Topics	Qualitative	Quantitative	Mixed method
Researcher	Result has strong relation to context of the study, and could be biased by the researcher	Research result is largely independent of the researcher	Can be difficult for a single researcher to carry out.
Cases	Suitable for small number of cases	Need larger number of cases	Only need a large number of cases when emphasising quantitative aspects.
Uses	Can describe complex phenomena, generate new descriptions, generate new theoretical statements	Use to test or confirm hypotheses, theories that were constructed before the data was collected.	Can address wider research purposes. Generation of a new theory or confirmation of the existed hypotheses both may be addressed by mixed methods (Creamer, 2011, pp. 1-2).
Collection of data	Long data collection. Researchers are the primary data collection instrument. Involved with narrative data	Relatively quick data collection time. Standardised data collection. Involves numerical data, measurable data	Benefits from a mixture of data. Narrative data may add meaning to numerical data; while numerical data may add precision to narrative data (Fry, Chantavanich, & Chantavanich, 1981, pp. 152-153,155).
Tolerance to changes during study	Amenable to changes occurring during the study.	Criteria that researchers used may not fully suitable for local research. Changes need to be addressed by re-constructed hypothesis or theory.	Qualitative components more likely to tolerate change.
Analysis	Analysis provide answer to why and how of the phenomenon	Analysis provides answer to how questions but less likely to answer why questions.	Benefits from advantages of both methods

(Table continue next page)

Table 8. Summary of research methods discussion (continued)

Topics	Qualitative	Quantitative	Mixed method
Knowledge produced	Knowledge produced may be unique and relate to only a few people	Knowledge produced may be too abstract and general	Produce more complete knowledge necessary to inform theory and practice
Conclusion drawn	Could be used to draw a tentative explanation from a preliminary work	Cannot draw a conclusion from preliminary data, due to its lower levels of significance	Conclusions may be drawn from a little qualitative data, and may be confirmed by larger-scale quantitative data.
Generalised	Have generalisation issues. Research findings may be confined to the context of the study.	Can generalise research finding when having large enough random sample sizes	Increased generalisability of the results

It is possible that the use of an anonymous tool may not totally reduce the influence of the remote and local instructors on the participants. Ultimately this is beyond any controls the researcher may attempt to impose. In a more wide-ranging study, it may be possible to compensate by distributing the research to involve more study sites, with different instructors, locally and remotely. However, the nature of qualitative study means that such influences cannot be avoided completely. In this exploratory study, qualitative methods may produce agreement or convergence of opinions relatively quickly, time constraints remaining an unavoidable limitation.

The limitation of adopting anonymous data collection then had the effect that the data collection process had to be designed to be precise. Any analysis that required a link between two data collection phases, i.e. the link between the questionnaire and a subsequent interview, had to be avoided. Therefore, the researcher chose to adopt a concurrent approach in order to eliminate the need to link phases of the study. This then gave the benefit of collecting confirmatory and contradictory data at the same time.

3.3.4.2 Summary

In summary, the author chose to adopt the following research approaches for the corresponding reasons:

- He chose mixed methods, emphasising qualitative data collection

- As the major part of the research was qualitative, it was suitable for the exploratory nature of the study.
- The minor quantitative part of the study was designed to see whether there was any convergence in the responses from the participants.
- The research employed anonymous data collection tools as more suitable means of addressing the unequal position between the participants and researchers, who were students and academic staff respectively.
- The research used a concurrent approach to avoid any connections between the researcher and the participants, unwanted because of the remoteness of the participants.

3.4 Research participants

3.4.1 Research participants for remote access laboratory

The first purpose of this study was investigating the suitability of introducing a remote access laboratory to use as a teaching medium in Thailand. The target population in this research study were undergraduate and graduate IT students in internetworking courses in a private university in Thailand. The questionnaire and the developed course materials were translated into Thai. Thai language was also a common spoken language between Thai students and the tutors and lecturers at Edith Cowan University throughout the pilot class.

In this research, topics of internetworking were selected to be used with the participants in the workshop. The content of the topics needed to be simple to suit the subsequent remote hands-on activities in a short workshop time. The fundamental topics and activities were selected from the main internetworking units of Edith Cowan University, which are CSG5106 Fundamentals of Computer and Network Technology, CSG5206 Internet Technology and Management and CSG5135 Network Technology 1. Basically, the remote hands-on activities designed for the Thai students were those involved in setting up a simple routing protocol such as Routing Information Protocol (RIP) and Enhanced Interior Gateway Protocol (EIGRP).

In this research study, a non-probability sampling technique was used to select the research population, after the Thai university had been provided with detailed information on the curriculum of the School of Computer and Security Science at Edith Cowan University.

Thai students may still be considered as only recently introduced to the use of e-learning environments (Lertkulvanich, et al., 2008). New distance learning environments may be likely to raise more concern in students unfamiliar with their use. Thai students, as they have less experience of distance education, may have stronger reactions to the distance learning environments, and may be able to compare them to their usual face-to-face learning method. This reason was considered to be a suitable selection condition for choosing a Thai sample population. Students with experience of remote access learning may not have been able to offer clear opinions.

The sample population was a group of remote access students from Thai universities. The population included 12 students who were interested in being involved with the study. Those students were enrolled in Cisco-based teaching units in their home universities and were already equipped with some basic knowledge and command of using Cisco network devices. Each student in this group had to attend a two hour class, which began by introducing them to the remote laboratory, continued with a lecture on basic routing knowledge, and finally offered the chance to complete a hands-on exercise through the remote facilities provided. After these two hours of activities, students were asked to complete an online questionnaire, in their own free time. The online questionnaire was implemented in Qualtrics as it was licensed to ECU. This was an anonymous data collection process and students had the choice of not returning the online form. Twelve student participants were interested in the study and attended the workshop, but only 11 students completed the questionnaire.

3.4.2 Research participants for non-technical skills investigation

As indicated earlier, the second purpose of this study was to discover the perceptions of internetworking students regarding soft skills development from university courses. The population chosen for this purpose was selected from local students in an Australian university. As a well developed country, Australian participants are well more familiar with distance education than the students in Thailand, who were used in section 3.4.1 above.

Sixty six students were interested in being involved in this study. Members of this sample population were asked to fill in their opinions in the questionnaire provided. The questionnaire was designed so that it could be completed in 20 minutes. This process again offered students the ability to make an anonymous contribution or to decide not to complete the questionnaire.

3.5 Survey instruments

Two actual survey instruments are presented in Appendix D and Appendix E. Appendix D is the survey instrument used for the evaluation of the multimedia rich online learning environment in Thailand. Appendix E contained the survey used for the research on non-technical skills.

3.5.1 Survey of remote access laboratory

The study involved a case study of a preliminary project of teaching an internetworking course to university level students in Thailand through a remote classroom. The aim of this pilot class was to introduce the multimedia rich remote internetworking laboratory and SMDs to the students, and to evaluate the learning environment and the usage of SMDs in internetworking education. Therefore, the interaction between the participants and the researchers were observed.

Questionnaires and observation were used for collecting data from target groups about the appropriateness of the learning environment that integrated multiple forms of network information for the participants. Learning difficulties were considered by the researcher, using observation of the laboratory hands-on exercises in these classes. After the classes, a link to the online questionnaire was provided.

Interviews were considered to be another suitable data collection strategy. However, due to the difficulties associated with distance and the organisation of the individual interview session with participants, no participants were willing to be interviewed.

The instrument used for multimedia research purpose (Appendix D) was modelled from Lawson and Stackpole's work (2006). It contained three sections:

1. Ethnic question and background of the participants
2. Evaluation of the remote access laboratory

3. Evaluation of the SMDs tools used in the study

3.5.2 *Non-technical skills investigation*

This investigation involved the use of an anonymous questionnaire by local Australian-based students, asking about their opinions on non-technical skills or soft skills in their internetworking course.

This instrument contained questions that can be divided into five parts:

1. Background of the participants and other general questions
2. General concern on non-technical skills
3. Self evaluation of the participants confidence about their non-technical skills
4. Self identification of the source for learning non-technical skills
5. Questions specifically related to communication skills

3.6 Data Analysis

The information from the questionnaire and interviews was analysed in order to report the results in documentary form. Although the research mainly focused on qualitative data, other appropriate statistical methods were also used to assist in interpreting the quantitative results and drawing conclusions from this research. The SPSS application software was used for analysing data from questionnaires. Notes were also taken to record any comments and further information from respondents which related to the research.

3.7 Ethical considerations

Due to the nature of the study, which involved the student and teacher relationship, a focus on ethical issues was important. The researcher was concerned about possible conflicts of interests between the participants and their universities' teaching staff. As it was imperative that the identities of the participants were unavailable to him; the researcher decided to employ an anonymous questionnaire to ensure their confidentiality.

This research had two separate purposes which were:

1. Introducing remote learning environment, and
2. Perspectives about non-technical skills

Both research purposes required slightly different ethics clearances from the University. Hence the researcher used separate applications which were approved at different times.

Part of the ethics application process was concerned with translation of the data collection tools. The correctness of the translation was approved by an independent member of ECU's academic staff who was fluent in both Thai and English. A translation confirmation letter and a copy of data collection tools in both Thai and English were then included in the ethics applications. Ethics permission was gained for both the online and offline versions of questionnaires used in this research.

Separate letters of information were given to the participants. The participants were able to refer to the details and purpose of the research. The addresses of the online data collection tools were also provided. The participants were given the option to reply with a consent form if they decided to participate in the interview process. The anonymity of possible interviewees was guaranteed and the researcher would not have been able to trace anyone back to the questionnaire to which they had earlier replied.

3.8 Constraints of this study

State Model Diagrams have been used by ECU internetworking staff and students for improving students' understanding of internetworking course content, and have also been tested with Technical and Further Education (TAFE) students in Perth, WA. Thus, the study did not generate sufficient information about the group for the analysis and research findings to be generalisable to a larger population. However, as mentioned above, the primary objective was to evaluate the State Model Diagrams as pedagogical tools; positive findings might provide the incentive to include the SMDs in future internetworking courses.

The School of Computer and Security Science at Edith Cowan University provided all the equipment necessary to perform this investigation. The network equipment in the laboratory was up-to-date and standardised for both educational and commercial environments.

This thesis is the major component of a Doctor of Information Technology degree, which was limited to a total of 2 years of research time. During the two years, all the research activities in the project were included, such as drafting the proposal, obtaining essential ethics clearances, developing data collection tools, organising the learning environment, collecting data, analysing data, and drawing conclusions. The research time frame was a limiting factor in this project. Clearly, the implementation of a broader research project was not possible within the limited time frame.

Another constraint of this study was the limited number of research participants, which led to a small sample size. The research was designed to draw conclusions from a study of experienced students only, those who had studied, or were currently studying internetworking, before participating in the research activities. This decision was based on the need for participants who would be able to compare and evaluate their past experiences against the new concepts that the research presented.

In particular, one of the research objectives, that related to the online multimedia-rich learning environment, needed the participants to be familiar with internetworking equipment and to be able to control its basic operations. Existing familiarity on the part of the participants was an important factor because the research activities allowed only two hours of workshop time for the participants to use the distance learning environment. Although the researcher could have provided the participants with more time to access the remote equipment, the two hours was considered to be the absolute minimum time requirement. These two hours were considered to be equivalent to the time on-campus students would spend in a face-to-face workshop during the researcher's university internetworking course. The participants were able to request more access to the learning environment if they felt it would be of benefit for their studies. However, the task involved in the online workshop, in this research, was simplified to suit the limited time of the online session.

Moreover, the research project was considered as a preliminary exploration, due to its novelty, to introduce multimedia-rich online internetworking education resources to Thai students who were not familiar with an online learning environment. Some unexpected outcomes occurred during the study. They will be further discussed in CHAPTER 7.

In summary, the issues limiting this study include:

- Limited study time
- Small sample size
- Need to recruit participants with internetworking experience
- Complex data collection process, while participants completed a relatively long class period
- Dealing with a remote site, with limited contact with research participants
- Preliminary and exploratory nature of the research project

The small research population, and the large distances between the researchers and research participants, made the selection of a suitable research method for this study a challenge. The use of quantitative methods for such an exploratory research project could not be justified because of the small sample size. Generalisation would not be possible. Therefore, the researcher adopted a qualitative approach as the main means of addressing the research questions.

However, purely qualitative methods also posed a risk to the data collection phase. As the research time was short, and therefore challenging, it could be argued that the adoption of purely qualitative data collection methods was inappropriate. In addition, the distance between the researcher and the participants was an added complication. Only data collection tools that compensated for that distance were suitable for this research. An online questionnaire, which also provided participants with the option of writing at length about their experiences, was created by the researcher, even though lower response rates were possible when compared to other survey tools. The researcher decided to adopt mixed methods and to include both qualitative and purely quantitative questions for the following reasons:

- Without the researcher being available on-site to answer any questions from the participants, purely qualitative questions may have generated a wide diversity of answers. Data analysis may have been overly complex. Answers to quantitative questions were pre-structured, assisting the researcher to focus directly on the research questions. Rich data was less likely to be generated for the researcher to analyse.

- The collection of quantitative data was likely to be useful for triangulating answers to qualitative or open-ended questions.
- Quantitative questions often reduce the time participants need to spend on the survey, and thus ease the data collection and analysis processes.
- The combination of these factors was deliberate, with the aim of increasing the response rate to the survey.

3.9 Summary

This chapter details the research methodology employed in this study. At its beginning the author explained the research framework in detail. The researcher chose to adopt a combination of qualitative and quantitative methods because these suited the unique and remote environment in which the research was conducted. Mixed methods were employed, and focused on the collection of qualitative data. The potential issues and reasons supporting the adoption of such methods were discussed. In general, the characteristics of this research were that it:

1. employed mixed methods: the main emphasis was on qualitative data, but quantitative data was also used where appropriate;
2. used concurrent data collection techniques; and
3. used an anonymous questionnaire and observation as data collection tools.

Furthermore, the target population and the data collection instrument were discussed. The author decided to recruit two separated participants groups, remote and local students, addressing two different purposes of the research. The author also described how initial concerns about ethical issues were considered and explained the processes by which the University's ethics applications were approved. Constraints affecting the completion of the research were identified and discussed in detail. Generally, the constraints of this study were:

- time limitation
- distance and specific requirements for remote participants
 - exploratory nature of the research project

CHAPTER 4 THE REMOTE INTERNETWORKING LEARNING ENVIRONMENT

4.1 Introduction

The internetworking laboratory of the School of Computer and Security Science of ECU was normally operated as a physical laboratory for local students and staff. This physical design would suit the construction of multiple network structures by students and researchers. However, this access was restricted to enrolled students and authorised staff. In order to provide a similar access from outside the university, the laboratory would need to be transformed. The outside students would need fundamental control access to the network equipment, while the access provided would need to conform to ECU security policy. This chapter discusses this transformation process from the physical laboratory to the restricted text-based only access and to multi-media supported access.

4.2 Physical laboratory design used in the experiment

As one objective of this research was to evaluate the use of a remote learning environment for Thai students, the normal operational laboratory at ECU had to be converted to support teaching in an online mode. The laboratory consists of 10 workstations, each with two PCs. The laboratory provides a central shared rack of fixed network equipment near the middle of the room. Figure 22 shows the design of the laboratory which included the central rack of shared equipment and 20 PC workstations around the room. Figure 23 shows the connectivity diagram of the physical equipment in the laboratory. Each work station had access to the central network equipment and the university network through three types of cables which are:

1. Console cable, or roll over cable, for controlling and configuration of the laboratory network equipment
2. Ethernet cable 1 and 2 for data communication sending/receiving to the laboratory network equipment
3. University network cable for accessing the production network of the university.

Physical settings like this not only promote the secure housing of the equipment, but also suit teaching purposes by allowing the laboratory to support the building of various network topologies using on the shared equipment. Furthermore, such a setting is standard in industry and can also be considered to be a part of the student learning experience (F. Hong & Bai, 2008; Sarkar, 2006). This shared equipment in the central rack also simulates a commercial working environment, which is another advantage compared to other designs such as providing the equipment predominantly at the student workstations. Using shared equipment may cause students to be confused about which equipment they are currently working on. This was one of the initial choices made in this design as it was thought to be better to allow students to make mistakes and gain experience in the laboratory rather than in their workplaces. Furthermore such confusion often tends to happen to students in the beginning stages; they will need to learn to overcome this issue to be able to work in a real environment, like the one simulated by this laboratory design. This distributed laboratory design, where small numbers of internetworking devices such as routers and switches are close to workstations, constitutes the reusable properties of the present setup. The security of the equipment, as it can be locked into the centralised equipment racks, is guaranteed.

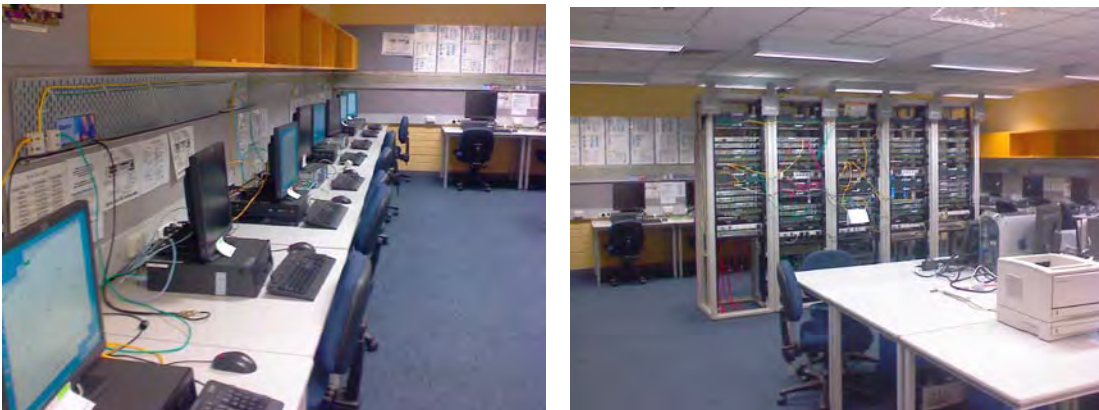


Figure 22. Physical laboratory design

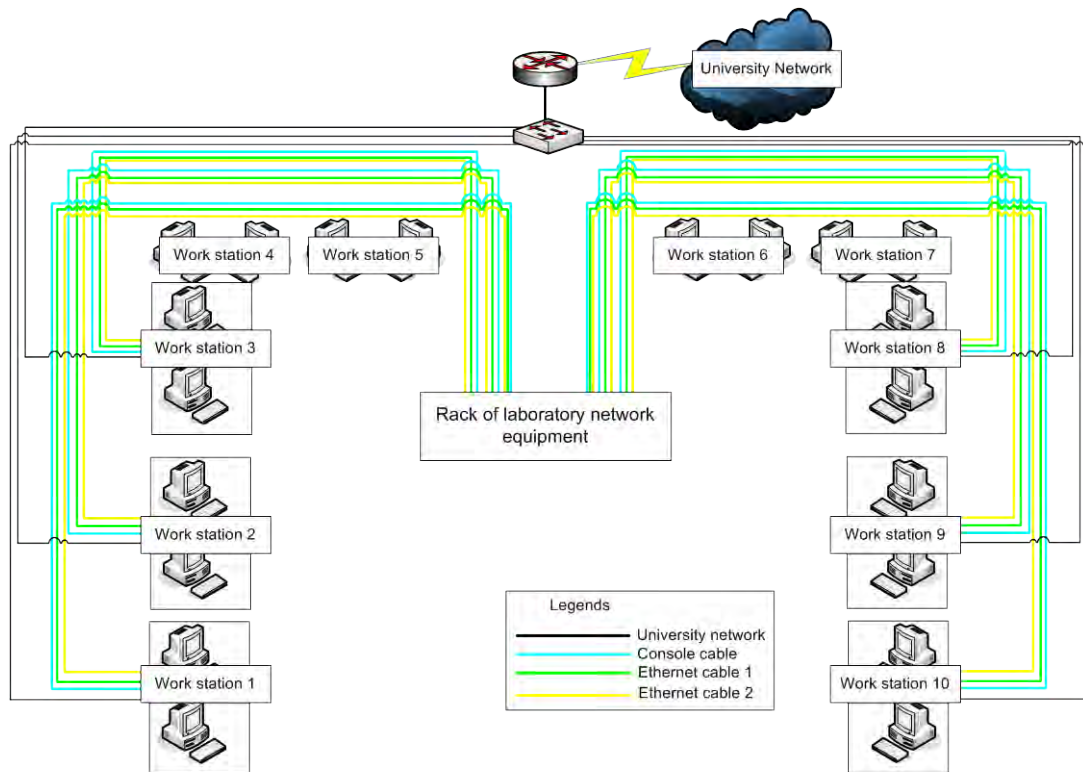


Figure 23. Diagram of physical laboratory

By having a reusable design, it is possible to convert this physical laboratory for local students to be able to use it with remote students.

In general, Tomov (2008) claimed that remote laboratories need to perform two tasks:

- (1) Provide an accessing mechanism, and
- (2) Facilitate the response of the equipment to the remote users.

The laboratory design in this research has to serve both purposes.

4.3 Current literature in remote laboratory design

Previous literature has presented the design of remote laboratory in a variety of different ways. Tomov (2008) described two constructive remote access architectures, *indirect access* and *direct access* architectures. Indirect access architecture provides access through an intermediate device controlling the laboratory equipment on behalf of remote users. On the other hand, direct access architecture acts as an entry point for general routine checks, for authentication or management purposes, and by later allowing the remote users to interact with the local equipment directly.



Figure 24. Indirect access architecture (Tomov, 2008, p. 2)



Figure 25. Direct access architecture (Tomov, 2008, p. 3)

Gerdes and Tilley (2007) provided a framework for building a virtual network laboratory, and debated the use of simulation software and the physical remote access laboratory. They suggested the use of a software-based virtual machine as a replacement for real servers and clients in the physical remote laboratory, but did not recommend the replacement of any network-related hardware with virtual PCs. They pointed out that the limitation of traditional remote access laboratories were that they lack multimedia collaborative tools (Gerdes & Tilley, 2007; Hua & Ganz, 2003).

Cao et al. (2009) were concerned with the building of a physical laboratory that could be re-used for multiple purposes. They facilitated centralised racks, the usage of virtual machines and simulation tools to provide a space-saving laboratory. Similar to the laboratory used in this research, their uses of centralised racks in the face-to-face laboratory eased the process of network re-construction while using various laboratory settings.

Abbott-McCune et al. (2008) presented a re-configurable physical laboratory that also benefited from integrating virtual machines acting as internal servers. The laboratory they proposed reduced the physical set up and tear down time between changes of class groups. Although their use of virtual machines reduced the number of physical servers and configuring time, multiple physical network cards were still needed to provide multiple connections to different virtual machines in a single server.

Rigby and Dark (2006) incorporated a *virtual patch panel* in their design to provide a laboratory that tolerated physical change. The virtual patch panel could be configured by adjusting the logical connectivity of equipment for any specific laboratory setting; however it required physical connections of all equipment ports. Yoo and Hovis (2004) demonstrated a similar concept where a virtual patch panel was implemented by using a normal network switch. Both laboratories could be reconfigurable without changes in physical connection. Similarly, the connectivity of configuration through the console ports was managed by the central console server. Figure 26 demonstrates the use of virtual patch panel and console server to provide a remote access laboratory.



Figure 26. Virtual patch panels design (Rigby & Dark, 2006)

The use of manageable console servers was also found in a commercial remote access laboratory's design, PacketLife.net (Stretch, 2008). The console server provides access to network equipment console ports, or configuration serial ports, over IP connectivity via a hyper terminal protocol such as Telnet and Secure Shell (SSH) (Stretch, 2010, p. 2). Various console servers were available for commercial use (Interworld Electronics, n.d.; Opengear, 2011). Figure 27 shows a console server, which can control 16 networking devices.



Figure 27. Console server (Opengear, 2011)

4.4 First generation of laboratory design

An attempt at remote access to the ECU laboratory was reported by Nuangjamnong, Maj and Veal (2008), where the objective was to provide access to network equipment for remote students. By providing a remote log-on through a network protocol like Telnet, it was possible for remote students to control the networking devices. The Telnet protocol can be used to connect directly to any enabled interface of the equipment; however, a console interface was specifically selected for this purpose. This is because it was the only interface that remained connected while the device was turned off or was in a power reload cycle. Therefore, an intermediate device was needed to maintain the connectivity between remote users and the local host. This intermediate device was an access server. This is a specialised router that enables multiple configuration connections.

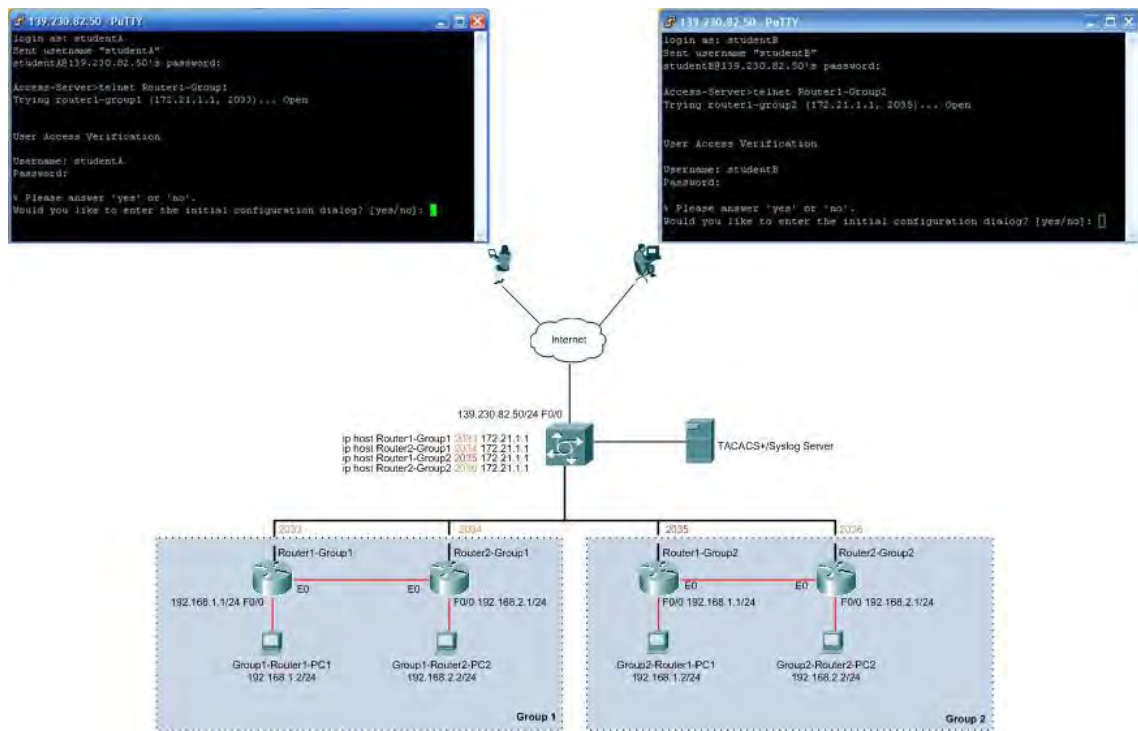


Figure 28. Diagram showing the first generation remote access laboratory with TACACS+ authentication server

There were security issues, for example the remote access laboratory needed an authentication process to screen out unauthorised users from interfering with an ongoing class. Figure 28 shows the topology of the first generation of the remote access laboratory which used the Cisco proprietary TACACS+ as an authentication server protocol. Local network equipment was divided into several equipment pods. The remote students could gain the access to equipment by login through TACACS+ servers via a Telnet session.

Tomov (2008) suggested using direct access architecture with network enabled equipment like routers. The first generation ECU laboratory design in this research also incorporated direct access techniques. Users needed to log-on to an access server which provided IP connectivity, then through the access server they could log-on to specific laboratory devices. Figure 29 shows the direct access architecture used in the first generation of the remote access laboratory in this research.

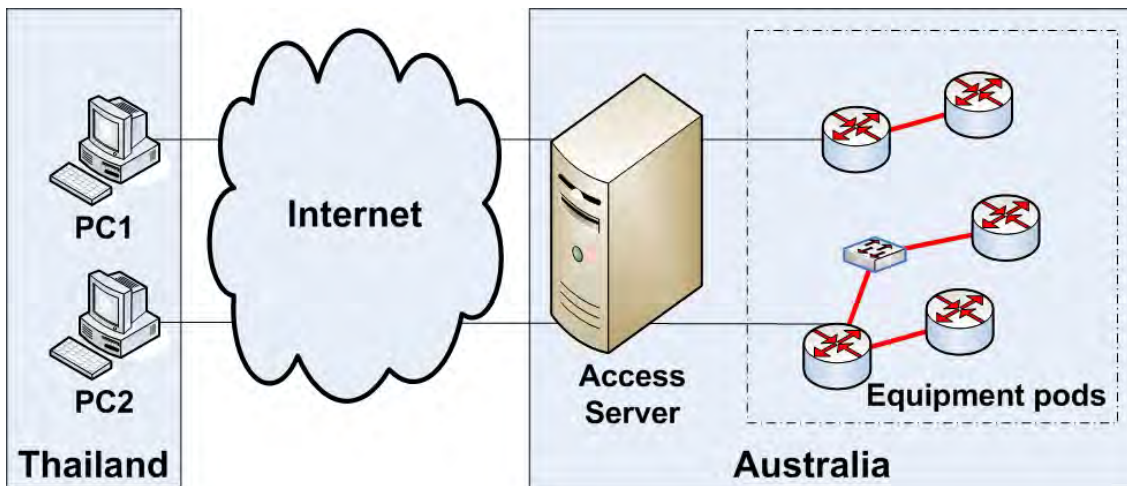


Figure 29. Thailand direct access through the access server (Makasiranondh, Maj, & Veal, 2011a)

Similar to the usage of console servers suggested by the literature (Rigby & Dark, 2006; Stretch, 2008), a simple router could be converted to provide the external IP connectivity while maintaining the internal serial-console connection to the equipment's configuration ports. This research used this router conversion as the access server for reasons of economy. The converted router was equipped with an NM-32A extension card (Figure 30). With four octal cables (Figure 31) and NM-32A, a single Cisco 2600 router provided access to 32 console ports, controlling 32 pieces of network equipment in the laboratory.



Figure 30. NM-32A extension card that used in access server



Figure 31. Octal cable

Remote users were able to connect directly to the access server while seeking authentication from the TACACS+ server. Once the access was authorised, the remote users could directly access the local network equipment.

Another security issue was solved by using a secured channel between remote users and the access server. The Telnet protocol was suitable for simple remote access, but involves a high security risk of being exposed as it is unencrypted. Therefore a more securely encrypted protocol, Secure Shell (SSH), was used to maintain the communication between remote users and the local access server. However, local communication between the access server to all equipment did not really need to be secured, as the traffic remained within the laboratory domain, where security was not a major issue. Hence, the internal traffic was managed by the more simple protocol, Telnet.

The text-based response of CLI was the only feedback that showed the status of the equipment in this first generation design. The limited text-based response was generally provided in most examples of remote access laboratories described in the literature (Hua & Ganz, 2003; Stretch, 2008; Yoo & Hovis, 2004). An internal pilot study already identified some disadvantages of providing only text-based CLI responses.

- The lower pedagogical value of CLI commands when building novice learning experience (Durham & Emurian, 1998)

- CLI was suitable for controlling by a professional who has already mastered the necessary skills
- Inadequate responses from text-based CLI only could confuse remote learners about the devices they were currently working on.

This research considered the pedagogical value of the laboratory to students, especially novice students who may not have yet developed their skills to a professional level. Therefore the provision of additional tools that could assist the students' learning processes was also considered.

4.5 Second generation of laboratory design

The poor pedagogical value of CLI in the first laboratory design was a major drawback. Although the design functioned well as a remote laboratory providing an essential control of text based communication, students were confused by the physical structure. For example, the students were confused about the status of the devices into which they were currently logged, and were unable to show their remote login screen to the local instructors. A second generation of the laboratory was designed to incorporate two supports to eliminate these problems, which were:

- The lack of graphical response to the remote student, and
- The lack of shared communication media between local instructors and the remote students.

The first support improvement was to incorporate SMD software in the second generation design. SMDs would act as an alternative graphical response to the students. The students could use SMD software, which was physically connected to the experimental network, accessing internal data about experimental devices without using the CLI text based command.

The second means of support involved providing shared central media between local instructors and remote students by using an application sharing facility. Generally, Remote Desktop Protocol (RDP) can be used to share the desktop screen of the computer in the laboratory (Lawson & Stackpole, 2006). However, this protocol was not used due to the security limitations on the current production network; specific protocols which require particular port numbers are prohibited in the campus network.

Therefore a web based conference system, such as WebEx (Cisco, 2011b), was considered to be a generally safe tool.

The second generation laboratory used WebEx's ability to share desktop applications which can pass control to anyone in the meeting by request. Therefore, this design required two network interface cards (NIC) for managing two different types of network traffic. These traffic types were:

- (1) The internal-experimental traffic to laboratory equipment, and
- (2) The external-Internet communication traffic.

The internal traffic was occupied by SMD software penetrating experimental equipment for their internal data. To be specific, the current development of SMDs used a non-proprietary protocol, the Simple Network Management Protocol (SNMP), in order to retrieve *network information* from network equipment (Figure 32). SNMP will be discussed in the next sub-section (see 4.5.1 below).

The external traffic was generated by WebEx to communicate with remote students via shared applications. Figure 32 shows the second generation of the remote laboratory design. The text-based only CLI connection of the first design was still preserved in this design. However, this new design used the Remote Authentication Dial-In User Service (Radius) server and protocol instead of TACACS+, to suit the new standard working environment of ECU. It was not the main purpose of this research to investigate security factor differences between the two types of servers.

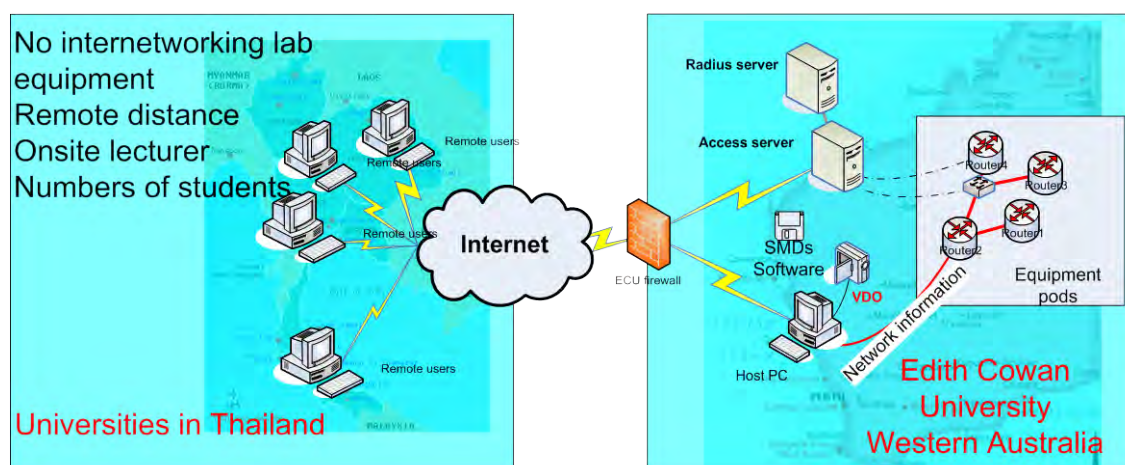


Figure 32. The second generation of the laboratory design

Remote students had a direct communication to the instructor via web conferencing consoles. Students were not only able to see the real-time video of the equipment but also were able to talk with the remote instructor at the same time (Figure 33). The author chose WebEx as it was a standard web conferencing tool from Cisco, the main internetworking equipment provider, although other tools that were available on the market would have been able to provide similar functionality. In the pilot trial, the author had tried running a remote session with other tools such as Elluminate (Elluminate, 2009), now integrated as the Blackboard Collaborate (Blackboard, 2011). Radvision Scopia (Radvision, 2011) and Adobe Connect (Adobe, 2011) were also considered. However, selection of such tools was beyond the scope of this research. The advantage of using web connectivity was its versatility and normal web traffic created less security concerns for both local and remote universities.

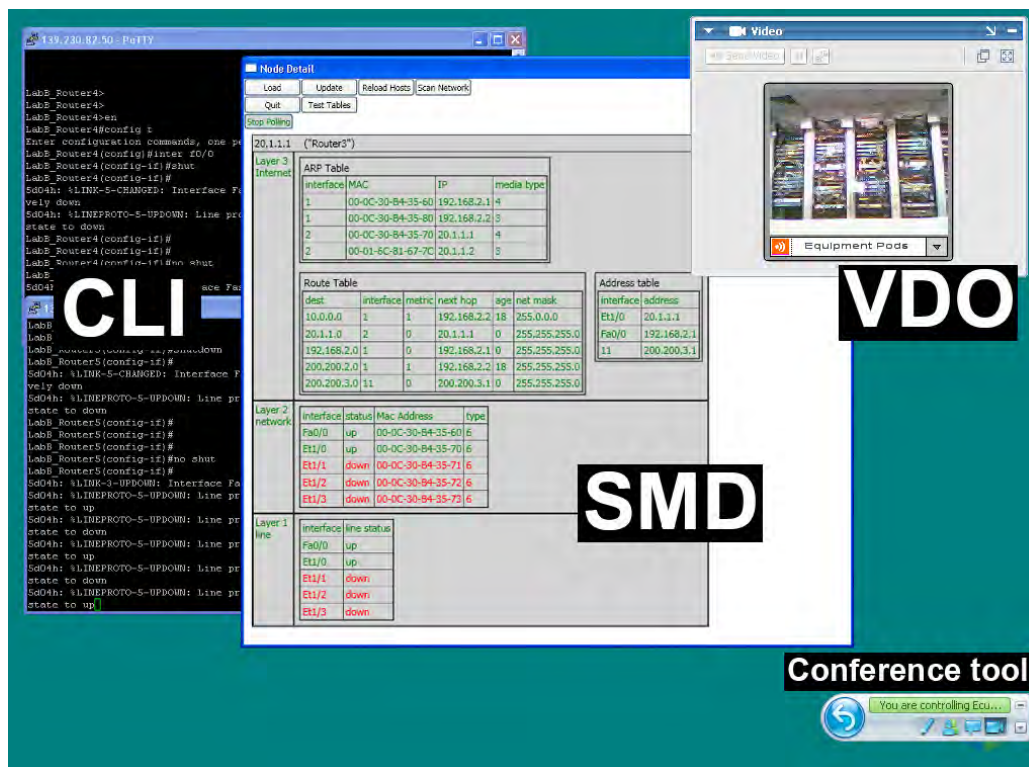


Figure 33. Learning environment that was provided to remote online students

One PC in each workstation (Figure 22) was installed with two Ethernet interface cards. This PC operated as the host PC. Without changing the physical structure, this design used one of the interfaces dedicated for handling communication traffic with external students and another interface handling the internal *network information* of laboratory

equipment (Figure 32). Furthermore, with two active network interfaces running on the same machine, the two different types of traffic had to be managed by manipulating the internal routing table of each PC.

Although a number of previous designs of remote laboratories suggested using *virtual connectivity* and *virtual machine* in the laboratory, this study was concerned to maintain a more realistic setting of the laboratory. These virtual techniques assisted the laboratory by reducing changes in physical structure and minimised misunderstanding. However, the remote students could still change the physical structure through a simple request to the remote tutor.

This design still faced scalability issues but was found to be suitable for the purpose of the preliminary research. The research was mainly focused upon the pedagogical outcome of introducing such tools to the remote students in a developing country, in this case in Thailand. Any enhanced features that would have introduced extra complications to student learning models were considered as unnecessary. However, further modifications to the laboratory design may be of benefit to students in further research.

The next sub-section will discuss the non-proprietary network management protocol, SNMP, which was the main implementation used for retrieving network information in the current SMD software.

4.5.1 Simple Network Management Protocol (SNMP)

The simple network management protocol (SNMP) is a standard protocol in the Internet protocol suite. It was defined by the Internet Engineering Task Force (IETF), for the purpose of managing computer internetworking. SNMP is an agent-based system, which every manageable network device implements in its own manner. Management of the network is done through the communication of multiple agents, which reside within devices. The management information can be retrieved and sometimes positioned through communication messages between agents, the network manager and a devices database. Basically, there are three elements of SNMP.

- Network management station (NMS), or network managers
- Agents
- Management information base (MIB)

Overall components of SNMP are shown by Figure 34. NMS is centralised equipment that gathers information about managing the network. The NMS communicates with network devices via request and response messages with agents. Within devices, agent software reacts to request messages by reporting the status of networking devices. The internal configuration information is stored in devices in the form of a database called the management information base (MIB). Each piece of information that an agent has retrieved or sent is referred to as a variable. The IETF has defined standards for the MIB and communication messages. Therefore SNMP can be used broadly across different network equipment and it is open enough to accept different implementations from different device providers.



Figure 34. SNMP components (Karris, 2004)

SNMP is simple because it is based on basic request and response messages. Therefore, the implementation of agents within networking devices is independent. SNMP can be used to manage various devices, from routers, switches, workstations, servers or printers, as long as the agent software resides within equipment. The agent software can be integrated into the devices' operating systems or in the form of independent services or daemon services. A daemon service is a program running in the background of an operating system. It will be in a disabled state until there is a specific request that re-activates the service.

A manager and agent communicate via user datagram protocol (UDP) in the TCP/IP suite. UDP is a connectionless protocol, which does not require confirmation messages

back from devices. Therefore, request and response messages consume less network traffic.

Request and response messages represent the communication channel that is initiated by NMS or the network manager. However, there is another message type that is designed for communication that is initiated from the agent side. This type of messages is a “trap” message. Its purpose is to let the agent report back to the manager about significant changes within devices. For example, these significant changes may be power down, broken connection or a change of routing policy. Trap messages can be used for both monitoring purposes and security purposes.

These core components of SNMP make networking management simple and can be used both scalable and expanded to suit both small size networks and larger sized networks.

4.6 Summary

This chapter outlined the development of the remote learning environment used in this research. It introduced the physical structure of the laboratory and relevant remote laboratory designs from the literature. The first generation of remote access laboratory provided only text-based CLI access to distance learning students, which was then developed into the current multi-media online learning environment that was used in the research.

The next two chapters will present results from this research, investigated in two aspects, which are:

- (1) The introduction of a remote access laboratory and State Model Diagrams (SMDs) to internetworking students in Thailand (CHAPTER 5), and
- (2) An investigation of non-technical skills building in internetworking education (CHAPTER 6).

This research involved different groups of participants, one in Thailand and the other in Australia. Therefore the results and analysis of the data will be presented in two separate chapters.

CHAPTER 5 Remote access laboratory and SMDs in Thailand

5.1 Introduction

This chapter reports the introduction of a remote access laboratory and State Model Diagrams (SMDs) to internetworking students in Thailand. In this chapter the author presents the results and analyses from the survey about introducing the State Model Diagrams (SMDs) in conjunction with the remote access laboratory for students in Thailand.

The ECU remote access laboratory was provided to Thai students via an Internet connection. During the workshop a brief online lecture was conducted by the author, who presented the concepts and the hands-on steps of configuring the basic RIP routing protocol between two routers. The author did not present in Thailand while conducting the workshop. However, the author did travel to Thailand recruiting a number of interested educational institutions. Traditionally, text-based command line interfaces (CLI) have been the only method used for accessing equipment in remote laboratories. CLI have specific advantages and disadvantages and had been described in 2.8 above. In this research, students were able to control the local network equipment via both the traditional access method and the additional SMDs. In other words, CLI was provided as the traditional access method, while SMDs were also presented as an alternative. SMDs were developed as computer software to depict local network information as pedagogically rich diagrams. This pedagogical value may help students create a valid conceptual model when learning in a challenging environment like a non-face-to-face laboratory of remote access equipment. Details of the laboratory, its structure, technical data and details of SMD software were presented in the previous chapter.

To sum-up, the findings of this research are collected in Table 9. Details of each finding and their discussion can be found in the listed section.

Table 9. Findings summary of remote access laboratory and SMDs

No.	Findings	Section
1	Students were dissatisfied with the access of physical laboratory.	5.2.2
2	Students lack confidence in using the remote access laboratory.	5.3.1
3	Students have a positive feeling in using remote access laboratory as a supplementary facility for doing self-practice exercises.	5.3.2
4	Students preferred a physical laboratory as a normal face-to-face classroom-based teaching method.	5.3.3
5	The major advantage of using remote laboratory was that the laboratory could be used to demonstrate an immediate practical example.	5.3.4
6	Students felt the disadvantage of using remote laboratory as it was confusing to use, lack of familiarity, lack of physical interaction and slower response time.	5.3.5
7	Students preferred to access to local instructors than remote instructors, when using remote access laboratory.	5.3.6
8	SMDs should be integrated with CLI and webcam when using with remote access laboratory.	5.4.1
9	SMDs found to be benefit to students when used with remote access laboratory, as they assist the learning process.	5.4.2
10	SMDs can assist distance learning of internetworking education.	5.4.3

Overall, this analysis is divided into three parts, which are presented in the following sub-sections:

1. Participants and their backgrounds,
2. An analysis of the evaluation of the remote access laboratory,
3. An analysis of the evaluation of using the SMD application.

5.2 Participants and their backgrounds

5.2.1 General background and number of participants

Participants were students enrolled in Information Technology and Business Computing courses at Saint John's University in Thailand, their home university. They were from both undergraduate and postgraduate levels. Saint John's University was chosen due to the initial common interests and relationships of staff for this research topic. Successful conduct of this research study was also the result of the well-developed relationship between the two universities, which grew during the time that a remote laboratory at ECU was being constructed.

Saint John's University also hosted a CNAP's CCNA course. Therefore, there was equipment provided to their students according to Cisco requirements.

Due to the constraints of limited time for the data collection phase and the need to ensure the availability of ECU's laboratory, the data collection process could not be prolonged to gain more participants. However, this was an initial proof of concept trial. The small number of participants could be considered as a major limitation of this study, as only 11 participants were fully involved. The reasons for this limitation will be discussed further in CHAPTER 7. However limited, these data did identify a number of potential issues when conducting a fully remote network technology class with Thai students in Thailand.

Originally, 12 participants were interested and attended the remote teaching and laboratory session. Ultimately, however, only 11 students gave their feedback in the questionnaire. Nine of the 11 participants identified themselves as undergraduate students, while the remaining 2 participants were postgraduates. All participants were enrolled on a full-time basis and were in the last year of their courses.

All participants were students who were enrolling in or completing the CNAP's CCNA units at Saint John's University. Traditionally, Thai universities provided lecture and laboratory sessions separately; this includes Saint John's. One of the completion requirements was that the students need to attend practical sessions in a laboratory.

Saint John's University had previously been listed as one of the Cisco's CNAP institutes (Cisco, 2009a), which have access to the simulation tool called Packet Tracer.

5.2.1.1 Discussion

It should be noted that all participants in this study were students who attended at least one session of the available laboratory, and so had the basic conceptual understanding and skills needed to configure routers via the CLI.

5.2.2 Comparison of home and host university resources

This section compares resources of computer network equipment between the home and host university. All participants confirmed that their university provided access to the internetworking equipment to support their study throughout the course. Although the provided equipment was in a mixture of a traditional face-to-face laboratory and simulation-based software from Cisco, the majority of participants were dissatisfied with the accessibility of the equipment. Six participants or 54% (see Figure 35) were not satisfied, whilst only 3 from 11 (27%) participants felt that the current equipment availability was sufficient for their requirements.

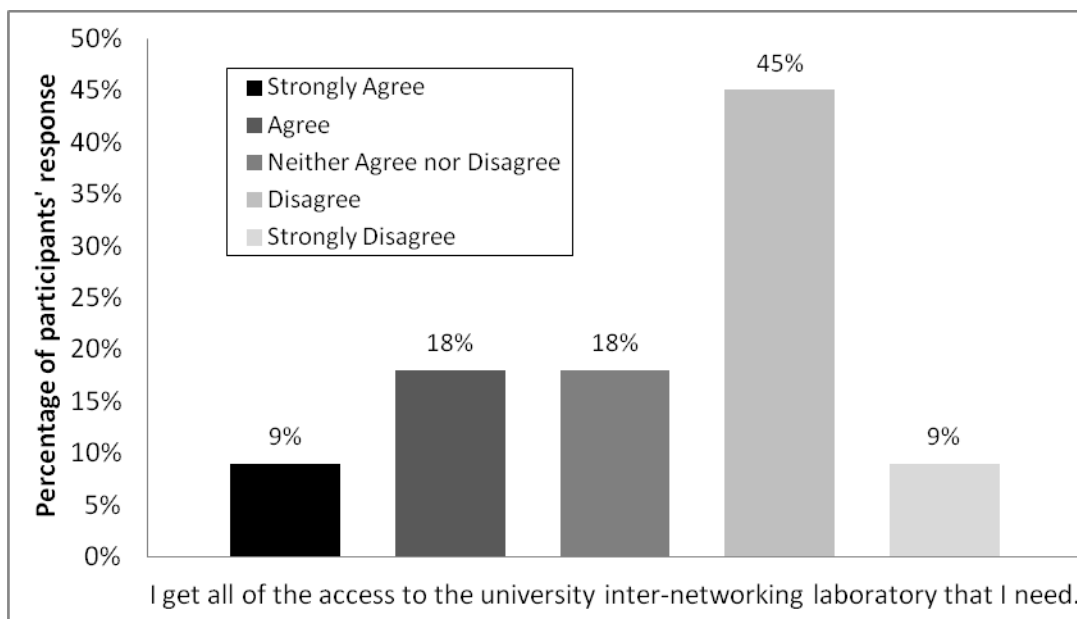


Figure 35. Participants' opinions on their access to their home university internetworking laboratory.

According to participants' further responses within this study, 10 to 30 students shared access to 3-5 routers, on average, in their university. Similarly, 6 switches were available for sharing between the same numbers of students.

5.2.2.1 Discussion

It was found that the majority of remote students were dissatisfied with their current access to the internetworking equipment at their university. Under the best circumstances, a group of two students could share only a single router and a switch. Hence there was the dissatisfaction with the equipment available at their home university. In contrast, the host university, ECU, provided 30 routers and 50 switches for a class size of 20 students or fewer. Therefore, each host university's student had access to nearly two routers and three switches. In other words, equipment within the host university was much more available and accessible. Furthermore, ECU students could also access the equipment during other lab sessions that were not part of their set laboratory periods providing that there was sufficiently spare places and equipment. Staff in the laboratories could often provide extra assistance to such students if they required help. Students could increase their learning opportunities through greater interaction with real equipment, rather than just sharing very limited resources.

Gallardo et al. (2007) suggested that the satisfaction with the learning depended on four factors:

- Content of the laboratory.
- User interface
- Ease of use, and
- Motivation

In this finding the lack of access to equipment did not satisfy the basic needs of students to complete the content of the laboratory exercises. This replicates the findings of Gallardo et al. (2007).

Further responses from the participants regarding their dissatisfaction are presented in Table 10.

Table 10. Specific comments from the participants showing dissatisfaction on their home university laboratory's accessibility

Reasons for dissatisfaction
Because it can be used only in the study session.
We can use the equipment only in the specific lab time.
The network room is available just for the hour of the class.
I have to study other units.
Because the laboratory was designed in particular to support network equipment demand, only CNAP network students can access it and only within a limited time. There is no further access to other generic or out-of-schedule use.

Participants sought further access to the equipment from their home university, by requesting access at other times. Almost all participants who commented felt that they were being restricted by being limited to access to equipment only in their laboratory time periods. This finding could also further support the inadequate student equipment accessibility during the student normal usage hours. A limited share of only a single router and one switch for every two students meant that students needed greater flexibility of access to the equipment to support their own study at their own pace.

Interestingly, although the simulation software by Cisco was also provided by the home university of the participants, the demand for more flexible laboratory opening times was still a valid one. The author suggested that the supply of a simulation-based laboratory was the second best approach. Various drawbacks of simulation-based software were discussed in section 2.10.4 above. These drawbacks included the inferior accuracy and steep learning curve associated with many simulation tools (Dan Wendlandt, et al., 2006). However, policies such as open laboratories or off-schedule generic use could be of concern to the university. Loosening administrative control of access to laboratories and equipment might expose it to more security breaches and the possibility of theft. Clearly, providing other equivalent means of equipment accessibility is still being sought by many universities.

The next section will analyse the results of using a remote access laboratory as an alternative means of offering students more flexible access to networking equipment.

5.3 An analysis of the evaluation of the remote access laboratory

The previous section's data concluded that the participants were likely to demand more access to laboratory equipment. An alternative could be offered by providing

simulation-based software or access to remote equipment. In this section, the author presents the results of introducing a remote access laboratory to the participants in Thailand.

5.3.1 *Confidence in using the remote access laboratory*

The first question asked the participants to offer their opinion of their confidence in learning computer networking by using the remote access laboratory provided by the host university.

Q1: I feel confident when learning computer networking in the remote access classroom.

The majority, 6 participants from 11 (54%) disagreed, 4 (36%) remained neutral and only 1 (9%) agreed with the statement above. This number means the majority did not feel confident when using only the remote access laboratory to learn their unit content.

Overall, the participants gave almost entirely negative comments about using the remote access laboratory. These negative comments have been collected and are presented in Table 11.

Table 11. Negative comments from participants about using remote access laboratory as a learning medium for computer networking course.

Reasons for not feeling confident when learning by using the remote access laboratory
We never have a chance to do any physical connection, which might mean we cannot remember when we try to use an actual laboratory.
I have just a few time learning by remote access environment.
In my case, I normally cannot follow the class like other. Sometimes I have felt much confusion.
It was not convenient to ask the remote facilitator, especially when we were facing a problem. It could be hard to solve.
Our institution has never taught in distance mode before.
I cannot see the physical connection of the equipment.
I don't understand.
I'm not sure that using the remote access laboratory could cover the whole semester load. Although, remote learning could save travelling time for distance students, the time allowed for the experiment was not enough to make people feel interested or measure the results of their learning.

Two comments were given about the short opportunity for laboratory usage and that there was not enough practice time for the participants to learn. Comments such as *“have just a short time for learning ...”* and *“... the experiment time was not enough to make people feel interested or to measure the learning result”* demonstrate more demand for time for the participants to familiarise themselves with the remote access system and how to operate it.

Other comments such as *“...never have a chance to do any physical connection...”*, *“It was not convenient to ask the remote facilitator...”*, *“... I have felt much confusion”* and *“I cannot see the physical connection of the equipment”* demonstrate a natural burden for students using remote access laboratories; a burden which is unavoidable and must be considered as a major challenge.

The data collected showed many challenges of introducing a remote access laboratory to long distance students in a developing country such as Thailand. Specifically, these are the issues:

- The lack of ability to provide a physical interaction for students,
- Slow responsiveness of the system and
- The ability to provide better access to remote instructor(s) so that access is comparable to traditional face-to-face instruction.

In addition to these challenges, students may need more time to familiarise themselves with the system. However, in order to provide a longer term service with the remote access laboratory a set of dedicated equipment may need to be provided. Also, it may be necessary to integrate the remote access laboratory more fully into the full semester's curriculum, and to conduct a lengthier study into its use, after a proof of concept based on a shorter session has been successfully achieved.

Although introducing the remote access laboratory was considered to be a challenge, the second question asked the participants about the value of its use as a learning tool.

Q2: Your university should use remote classrooms as a main tool for teaching computer networking?

The majority of the participants, again 6 from 11 (55%), agreed with this statement, 3 (27%) disagreed and 2 (18%) remained neutral. This level of agreement could mean that

the participants realise the value of using a remote access laboratory. Some feedback from the participants was collected and is displayed in the following table.

Table 12. Positive and negative comments from participants about their university applying a remote access laboratory as a teaching tool.

Position	Reasons for agreement or disagreement with using the remote access laboratory as a learning tool
Agreed	We don't have some of the equipment that the remote laboratory provided.
	It is convenient to learn
	It will create a new way of teaching and learning
	It will help the students to learn more practical knowledge
	It is a new knowledge for the students
	It will reduce the cost of facilitating computer network equipment
Disagreed	If I have to study in a remote online laboratory, I won't be able to understand the knowledge at all.
	We don't have our own remote access laboratory available for us to use.

Participants' comments show they recognise the value of the remote laboratory. Comments such as "... *help students learn more practical knowledge ...*", "... *reduce the cost of facilitating equipment ...*" and providing more equipment than the home laboratory, demonstrate all positive values of remote laboratory. Furthermore, negative comments such as "... *I won't be able to understand the knowledge at all ...*" and "... *we don't have our own remote access laboratory ...*" were, in fact, not showing the drawbacks of the remote laboratory. However, those negative comments pointed to the position of remote laboratory as a complementary facility and even pinpointed the need for institutions to provide remote laboratories as a long-term service rather than as an external short-term service, as occurred in this experiment. At this stage, the experimentation was meant to be an evaluation of the introduction of a remote laboratory only. Therefore, a fully implemented version of such a facility could eliminate this negative feedback. Detailed focus on the possibilities for remote access laboratories in the Thai education system will be presented in the next section.

5.3.1.1 Discussion

Although the participants were previously trained with Cisco's CCNA networking equipment, the majority of participants lacked confidence in using the remote access laboratory. The main reason was the lack of familiarity with the new learning

environment. A further factor was the lack of physical interaction within the remote access laboratory. This is because novice students felt more familiar with the concrete level of teaching, which was in line with the findings of McDonald et al. (2001). Physical touches in handling devices assist students in learning concrete concepts. However, the remote access laboratory may have a value as a supplementary facility provided to students as an additional option. This finding corresponds to those of Woltering, Herrler, Spitzer and Spreckelsen (2009); who suggested that remote access learning facilities may be useful as a complementary tool.

5.3.2 The usage of laboratory for self-practising

Analysis of the previous section (5.3.1) showed that the participants were not comfortable working with a remote access laboratory alone. However, they did see this facility as a complement to the available system. This section will compare the participants' perceptions of a remote access facility with a traditional hands-on laboratory and a simulation-based laboratory, when they were completing laboratory self practice exercises, outside normally scheduled classes.

Question 3 asked the participants to compare using remote access laboratories and traditional hands-on laboratories for self-practice.

Q3: When compared with the traditional hands-on laboratory, I prefer to do the lab exercises via the remote access laboratory.

Ten participants responded to this question. The majority of 7 participants (70%) agreed with the statement, preferring a remote access laboratory to do their lab exercises. Two participants (20%) were neutral and only one participant (10%) disagreed. Comments in Table 13 are from the participants.

Table 13. Reactions of participants to the statement in Q3.

Position	Q3: When compared with the traditional hands-on laboratory, I prefer to do the lab exercises via the remote access laboratory.
Agreed	Because we can use the correct equipment with a correct connectivity, we can apply more to the real situation
	As we can see it in real life.
	In this way, I can learn at the same pace as my friend.
	It will help the student to have more way to learn.
Neutral	Don't understand
	It seems traditional classroom would be better, as students can meet the lecturer, tutors immediately
Disagreed	Because I can work better in a traditional hands-on laboratory.

The strong points of practising the laboratory exercise by using the remote access laboratory has been picked up by the participants. One of the strong points was that the physical connection of the laboratory was already set up, so students could bypass the physical step and focus on configuration. Also, the layout of the equipment in the remote laboratory imitated a real work environment, by using racked equipment and showing connectivity as in the server room. Further comments indicated that providing the remote access laboratory as an additional resource could help students reinforce their learning in the formal classes.

On the other hand, negative responses to the usage of the remote access laboratory for practice were also presented. Some concerns were raised about communication, and the turn around time involved, when it was necessary to contact lecturers or tutors. Again, this drawback was a natural difficulty associated with long distance education.

The next survey question compared the participants' perceptions of the comparison between remote access laboratories and simulation laboratories, when each was provided as a facility for self practice.

Q4: When compared to the simulation laboratory, I prefer to do the lab exercise via the remote access laboratory.

Results showed that the majority of participants, 6 from 11 (54%), preferred the remote access laboratory, 3 (27%) remained neutral and 2 (18%) disagreed with the statement

and preferred the simulation laboratory. Further feedback from the participants is shown in Table 14.

Table 14. Responses of the participants to the statement in Q4.

Position	Q4: When compared with the traditional hands-on laboratory, I prefer to do the lab exercises via the remote access laboratory.
Agreed	Because we can work with real equipment
	We can try a new learning style
	In case of distance learning, I cannot entirely rely on simulation-based laboratory.
Neutral	We didn't have much chance using the remote facility. We have used it only on the demonstration time and there was a lot of delay.
	I don't understand
	Simulation software could work out well with some topic. Whilst a specific topic such as WAN technology, remote access lab could be one of choices that help students understanding.
Disagreed	Simulation tools are similar to real equipment
	I prefer working with real equipment

Although the majority of participants preferred remote access laboratories to simulation laboratories, the supporting reasons they gave were not completely convincing. Two supporting positive comments were “*We can try a new learning style*” and “*In case of distance learning, I cannot rely on simulation-based laboratory*”. These positive comments were related to long distance learning style which was considered as being new for the participants. Other comments stated one strong point of remote access laboratory, which illustrated the students’ preference for working with real equipment instead of a virtual or simulated environment. All positive comments showed that there were drawbacks in adopting simulation tools as a primary long distance teaching solution.

Meanwhile, negative comments were more specific and pointed out the problems of adopting a remote access laboratory instead of a simulation laboratory. Unenthusiastic comments included the slow response of the system, the competing reality of modern network simulation tools and the wider abilities of network simulation tools. These negative comments strongly challenged the adoption of remote access laboratories in new countries such as Thailand, especially when the necessary learning styles were considered to be new and students had no earlier experience with long distance learning.

5.3.2.1 Discussion

Findings suggest that students believed in the convenience of using the remote access laboratory as a self practice tool. Although, the ability to generalise from this confined qualitative data was limited, this finding supports Kumar et al. (2010) where unsupervised learning tools were employed in an effort to encourage students to learn (Lim & Holt, 2011). Furthermore, students need realistic equipment in order to relate their conceptual understanding to physical hardware (F. Hong & Bai, 2008, p. 2582). The realistic setting of this remote equipment is superior to simulation tools. The preference of self-learning through the use of unsupervised tools was also found in the students; however, they might need the additional guidance to understand fully internal operation of equipment (Cappelle, Evers, & Mitra, 2004), especially internetworking equipment which was considered as black-boxed to students (Maj, Tran, & Veal, 2007, p. 356).

5.3.3 Preferred types of laboratory for classroom-based learning

The previous section discussed the type of laboratory in which students preferred to practice outside normal class sessions. This section introduces the results of the survey, which asked students to nominate the type of laboratory they preferred to be used for normal classroom lectures. This question asked the participants to vote for their preferred learning style, between using traditional face-to-face laboratories, simulation tools, remote access laboratories or just listening to lectures without any laboratory sessions. The participants' responses to the question are shown in Figure 36 below.

Clearly, the majority of the participants preferred using a traditional face-to-face laboratory for doing practical hands-on exercises. Almost all participants, 8 from 11 or 73%, preferred a traditional laboratory method. In comparison with other types of laboratories, the remote access laboratory received a very similar vote to simulation tools by 3 (27%) participants and 2 (18%) participants, respectively. More specifically, 5 from 8 (63%) participants, who preferred traditional laboratories, disagreed about using a remote access laboratory and even preferred to use simulation tools. On the other hand, almost all participants 8 from 11 (73%) did not prefer learning from only a lecture without laboratory practice. Supporting comments from the participants about their vote are presented in Table 15.

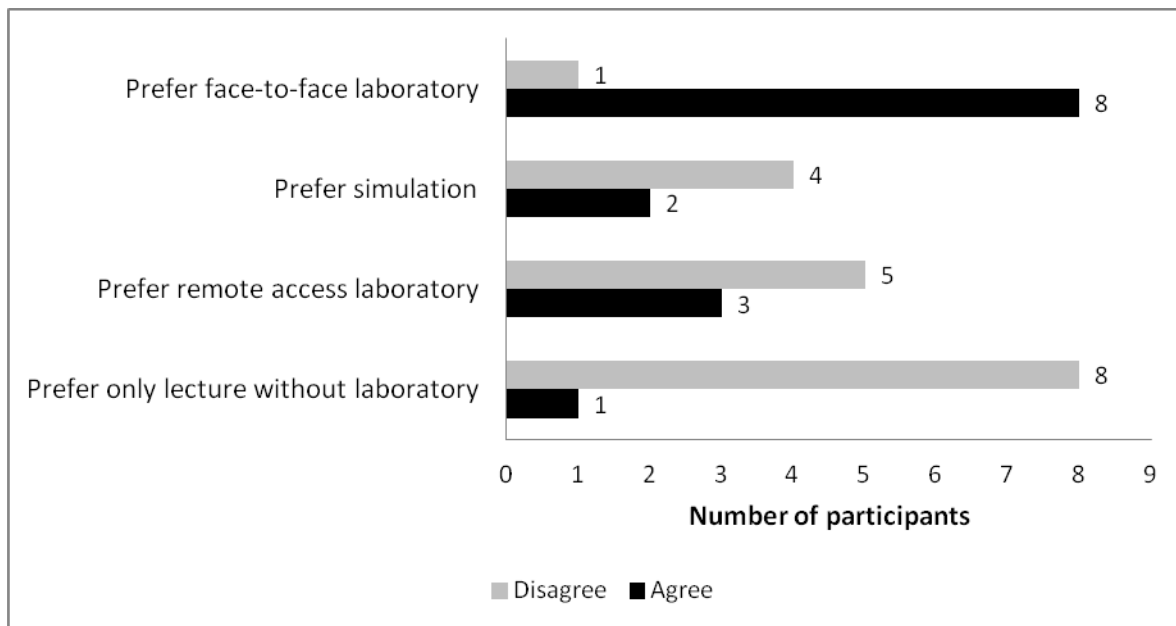


Figure 36. Agreement proportion of the participants' preference of each laboratory.

Table 15. Further comments from the participants about their preferred laboratory type.

Q12
When using a face-to-face lab, we can touch the equipment. Hence we can gain more experience from them.
Traditional laboratory or the simulation tools can help practicing the usage of equipment more than the lectures alone.
Because students can practice working in a reality.
By learning with real equipment, we can gain more knowledge, because it is practical.
I would like to learn by using every available method, and then I can understand the lecture from different points of view.
It is easier to understand while learning in a normal laboratory. The simulation can enhanced my knowledge through the extension of example.
I preferred remote access laboratory, because sometime I cannot digest the knowledge and understand everything in the lab.

Further feedback from the participants indicated that laboratory exercises were an important element in conjunction with lectures. Laboratory exercises using real equipment in a traditional style were preferred over the other choices. According to the feedback, the advantages of the traditional laboratory were that students gained more experience, while the traditional laboratory offered the highest degree of reality and was easier to understand. The participants believed that simulation tools could expand their

knowledge by acting as a supplementary tool, even to a greater extent than remotely accessing real equipment. The reason could be that these participant groups were exposed to simulation tools for a long time and hence had gained familiarity with them. Besides, the realism of a remote access laboratory may therefore not have been deemed necessary.

5.3.3.1 Discussion

This finding could indicate that students are more comfortable practicing with physical laboratory sessions in conjunction with lectures. This is corresponding to Cao et al.'s (2009) findings that stated the appreciation of feedback in the physical laboratory from students. Although the use of remote access laboratories in teaching may found to be as efficient as physical laboratories (Aravena & Ramos, 2009; Lawson & Stackpole, 2006; Sicker, Lookabaugh, Santos, & Barnes, 2005), the hands-on approaches in the face-to-face laboratory are regarded as far superior (Heise, 2006). Corresponding to previous research (Corter et al., 2007), signs of students' appreciation for the convenience of the use of a remote laboratory were found, but they still preferred learning in the traditional hands-on local laboratory. Students needed the laboratories to be realistic, with less complications, in order to understand internetworking concepts which were not readily visible (Goldstein, et al., 2005, p. 223).

The first priority of the exercises was to build upon the traditional face-to-face laboratory to set up a realistic understanding (Ma & Nickerson, 2006, p. 14). Some situations, such as operation time and security policy, may limit access to physical laboratories which would then cause remote access laboratories or simulation tools to be used as supplementary facilities. However, universities may also need to promote a critical attitude amongst students when they are using simulation tools as to the constraints of the simulation.

5.3.4 Benefits of using remote access laboratory

Further investigation focused on the potential benefit of using a remote access laboratory. Sections in the questionnaire circulated to the participants asked for their opinions on each potential benefit. Participants could express their opinion by voting to agree or disagree with each statement about benefits. Overall participants' agreement percentages are shown in Figure 37.

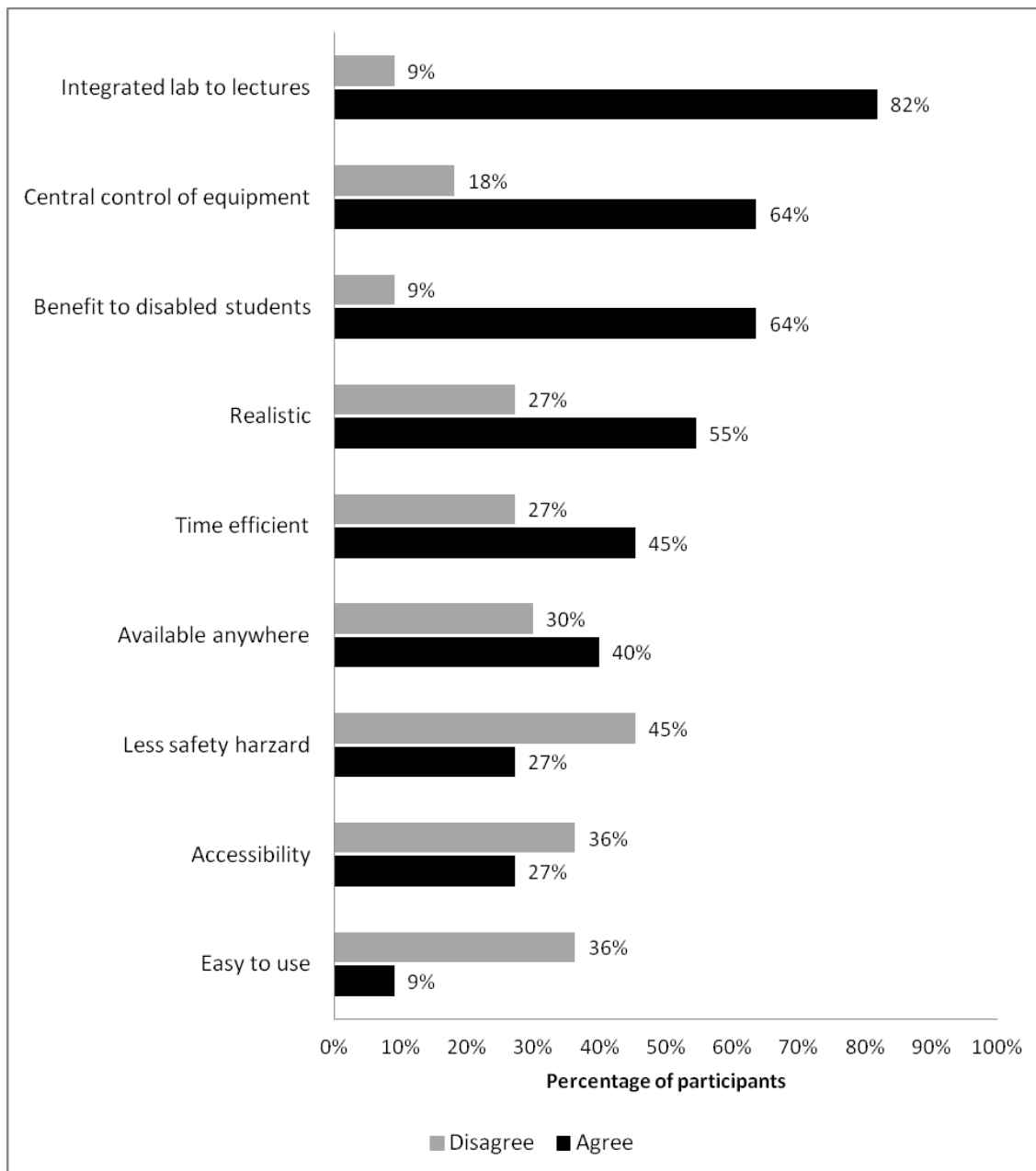


Figure 37. Participants' percentage agreement with the benefits of the remote access laboratory.

The most accepted benefit of the remote access laboratory was its ability to be integrated with normal lecture classes. Participants believed that remote access laboratories can be used immediately with any lectures to demonstrate the on the spot reactions of the equipment to any commands. Almost all participants agreed on this statement, by 9 (82%) out of 11. This benefit showed the potential of using the remote access laboratory as a lecture tool. Although, simulation tools could also carry out this function, the correction of results and how far the tool could be supported were in question (Heise, 2006). The results from section 5.3.3 above could also support the

claim that students were likely to learn when practical elements were introduced (McDonald, et al., 2001), rather than from lectures alone (Cao, et al., 2009; H. Hong & Shengzhong, 2009). Therefore, remote access laboratories may situate themselves as a supplementary teaching tool, by providing instant results during the ongoing lecture.

The other agreed advantages of the remote access laboratory were its ability to control laboratory activities centrally and its potential benefits to disabled students. Seven participants (64%) from 11 agreed on these two benefits. Furthermore, the realistic experience offered by the laboratory was mentioned by 6 (55%) out of 11 participants. Normally physically-handicapped students, who cannot travel or who have problems accessing different equipment on different rack heights, were limited to only the simulation tools provided. The remote access laboratory could benefit these students by offering them a realistic laboratory which could be controlled from a single machine.

A similar number of participants agreed and disagreed on the statement that said the usage of remote access laboratory could be timely and efficient. Five participants (45%) considered that using the remote access laboratory was more effective use of their time than using the traditional laboratory; in contrast, 3 participants (27%) did not agree. Similar numbers of participants agreed and disagreed about the availability of the remote access laboratory. Only 4 participants agreed that the remote access laboratory could be available anywhere; 3 participants disagreed with the same statement.

On the other hand, the majority of the participants did not agree with the following statements of the advantages of the remote access laboratory, namely: (1) the ease of use of the laboratory, (2) its accessibility and (3) the safety of the laboratory. The participants did not believe that remote access laboratories are easy to use, provide good accessibility or have less safety hazards than traditional laboratories. Four participants (36%) disagreed on the simplicity of the remote laboratory, and felt that it was not easy to use; whilst only one participant (9%) felt comfortable with the easiness. Similarly, four participants (36%) believed that the remote access laboratory could not provide good accessibility when compared to the other types of laboratories. Apparently, they currently have regular access to simulation tools and may have felt that accessing them was more flexible than that provided by the remote access laboratory. Five participants (45%) disagreed that the remote access laboratory could have less safety hazards than traditional laboratories.

The participants also gave comments about further benefit of remote access laboratory. These comments are shown in Table 16.

Table 16. Further benefits of using a remote access laboratory.

Q13: Further benefit of using remote access laboratory
It will help the students to have a new experience of controlling and using remote equipment.
I agree with the benefit of remote access lab. Because it gives me a chance to practice working with other people and can be used in reality.
Suitable for the place that don't have any equipment available.
Remote classroom is good and suitable for long distance learning or online courses. Especially it can be expanded to use in a wider area.
Many advantages as it allows handicapped people, who cannot commute to school, are able to learn without the need of travelling.

Feedback from participants further emphasised the remote laboratory's usability in long distance education, especially for disabled people. They could confirm the participants' positive opinion of the benefit of combining remote access and the ongoing lecture class.

5.3.4.1 Discussion

The participants believed the advantages of the remote access laboratory are related to

- Supporting lecture sessions,
- Benefiting disabled students, and
- Offering realistic control of the equipment.

The results could also support the claim that students were likely to learn when practical elements were introduced (McDonald, et al., 2001), rather than from lectures alone (Cao, et al., 2009; H. Hong & Shengzhong, 2009). The agreement on the benefit of using a remote access laboratory to support disabled students corresponded to the works of Armstrong and Murray (2007; Murray & Armstrong, 2009). Furthermore, the agreement of realistic nature of the remote laboratory was close to traditional laboratories supported (Gerdes & Tilley, 2007). The agreement on usage difficulty supported Sicker et al.'s (2005) conclusions, but opposed the finding from Corter et al. (2007). The result from Corter et al.'s (2007) work concluded from students of cross-subjects and they may not have direct experience using both a simulation and a remote

laboratory equally. However, the lack of ease of use of remote access laboratories may be an inhibitor of students' adoption of using the tools in classes (Martínez-Torresa, et al., 2008).

5.3.5 Disadvantages of using remote access laboratory

Section 5.3.4 above presented the participants' opinions on the advantages of remote access laboratories. In contrast, this section focuses on the disadvantages. Parts of the questionnaire circulated to the participants asked for their opinions on each potential disadvantage. Participants could express their opinion by voting to agree or disagree with each disadvantage statement. Overall participants' percentages of agreement are shown in Figure 38.

The majority of the participants agreed with all statements in the questionnaire about disadvantages of remote access laboratories. In other words, more than 50% of the participants agreed on every negative aspect of remote access laboratories.

The top three statements about disadvantages with which the participants agreed were about (1) the laboratory causing some confusion, (2) students not being sure about which devices they were currently working on and (3) concerns about the correctness of the physical setup. All these statements about disadvantages were agreed to by 8 (73%) from 11 participants.

Further results showed 7 participants (64%) felt uncomfortable and restricted by the limitations of the fixed physical topology that the remote laboratory provided. The same number of participants agreed about the slow response of the laboratory.

Six participants (55%) agreed about the other three disadvantages, which were (1) the lack of physical interaction with the remote laboratory, (2) feeling disconnected from reality and (3) the lack of timely responsiveness when communicating with the remote instructor.

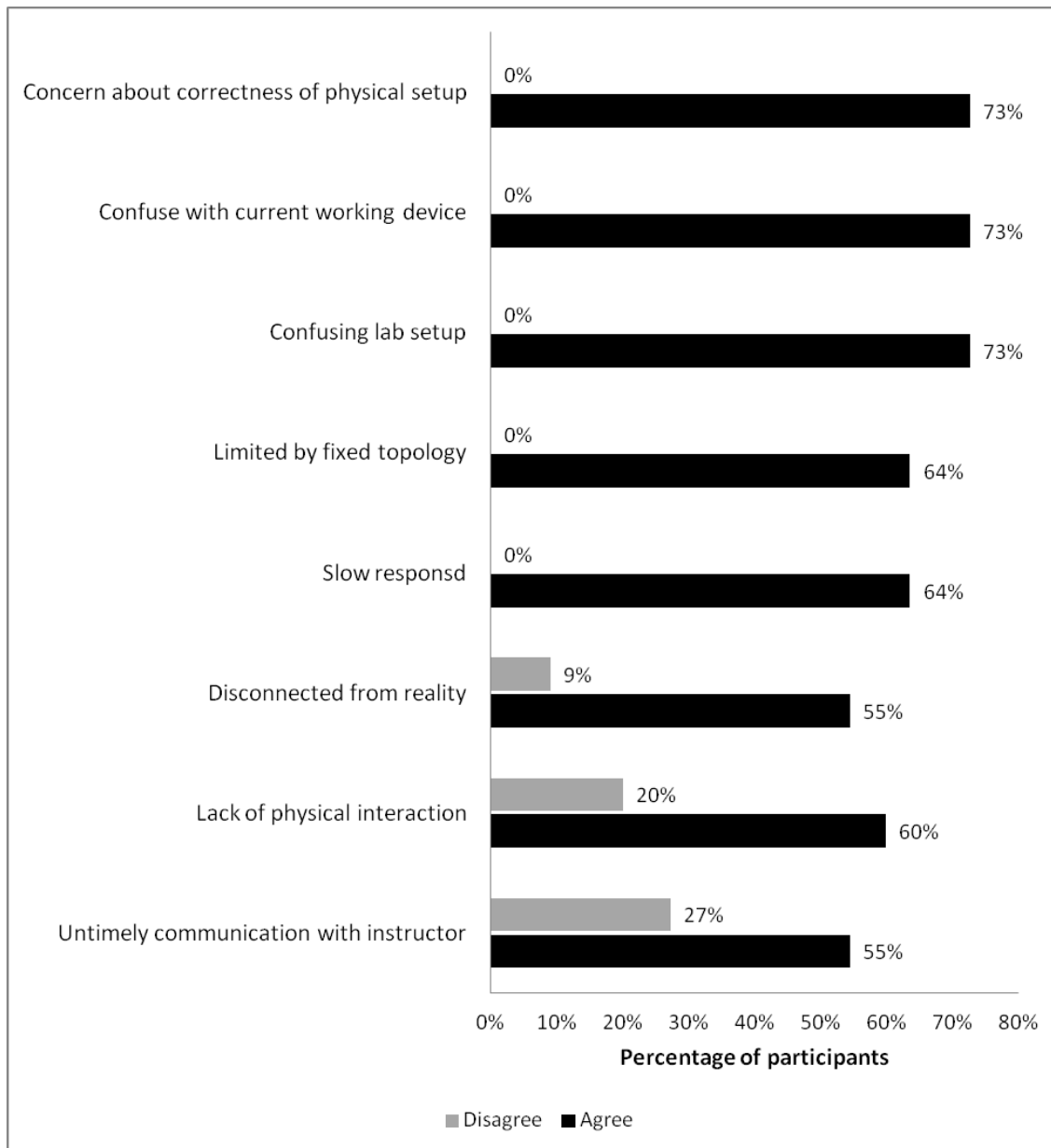


Figure 38. Overall participants' agreement percentage on the disadvantages of remote access laboratories.

The participants also expressed further opinions on the disadvantages of using the remote access laboratory. These further comments were collected and are shown in Table 17 below.

Table 17. Further disadvantages of using remote access laboratory.

Q14: Further disadvantages of using remote access laboratory
Virtually cannot visualise the sense of real equipment, may cause confusion when configuring the network equipment.
I cannot work conveniently, because I cannot touch the equipment myself
Depending on the person needs of how much experience of using networking equipment. Learning Cisco is learning how to use the knowledge and apply them in a real world. Therefore, I want to be taught with real equipment in a real setting of traditional face-to-face laboratory, because then I can use that equipment on hand. Also, if the equipment faces a problem, then I will know how to fix it.
To me, I don't think we have any disadvantage.
Have some disadvantages of misunderstanding, because we are not close with the equipment or using them in a touchable laboratory.

Many comments were concerned with the use of real equipment remotely, as the participants were not used to the remote environment and could not get the feeling of really working in such an environment. Especially, there were complaints about confusion when swapping between different pieces of remote equipment. The lab setting used in this study involved only 2 of the simplest routers and participants were easily confused about which router they were operating. The complaints were mainly focused on the non-physical or intangible access issues of the remote laboratory. The complaints showed that the participants may have needed more time to familiarise themselves with the environment and to spend more time on understanding the topology of the interconnection of equipment before they could even begin the laboratory tasks.

5.3.5.1 Discussion

The traditional setting of the face-to-face laboratory may not have a problem of equipment confusion as the users can see the interconnection immediately from the physical setting and can physically swap or change the equipment on hand. The results showed that the lack of interaction, feeling of disconnection from reality and the confusion of remote laboratories supported previous research. For example, Corter et al. (2007) compared hands-on, simulation and remote laboratories in other engineering subjects and found a similar conclusion about students' opinions of lack of reality in

remote laboratories. Students in Sicker et al.'s (2005) study also found that the usage of remote laboratory was hard and frustrating. However, this research used a real-time remote laboratory which was not similar to that in Corter et al. (2007), where students also voted the response to be slow. In general, responses from real equipment accessed via remote laboratory could not compete with the immediate-unrealistic responses from simulation tools. In the near future, by 2020, the Australian National Broadband Network (NBN) is due to be ready (Department of Broadband Communication and the Digital Economy [DBCDE], 2010). The NBN may relieve the slow response issue for users in Australian rural areas; however, it may not cause a significant change for the users from other countries.

Potential drawbacks of the remote access laboratory, such as usage difficulty and the feeling of unrealistic presence, may be solved by allowing more time for participants to become familiar with the laboratory setup. However, in the real ongoing network class, in which the topology of the laboratory may be changed for each lab task, a considerable amount of familiarisation time may need to be introduced to class schedules.

5.3.6 *Local and remote instructors*

Local and remote instructors in the remote access laboratory make a critical contribution to students' learning processes. This section analyses the results from the part of the questionnaire which asked about this contribution. Questions 16.1, 16.5 and 16.6 all asked about participants' different beliefs about the types of instructors needed to be provided in the remote access laboratory.

Question 16.1 asked for the participants' feelings about the availability of a remote instructor for the remote access laboratory. Question 16.5 asked their opinions of the need for a local instructor while they were carrying out an exercise. Furthermore, question 16.6 asked about their feelings while they were working independently, without any local instructors being present. The participants expressed their opinion by voting on a Likert scale of five points, ranging from strongly disagree to strongly agree. Participants' answers to these questions are shown in Figure 39. This is not an absolute evaluation of remote instructors versus local instructors as only one remote instructor and one local instructor were involved in this study. The data may demonstrate a

potential issue dealing with making local or remote instructors available; however, more research is needed in order to generalise this specific conclusion.

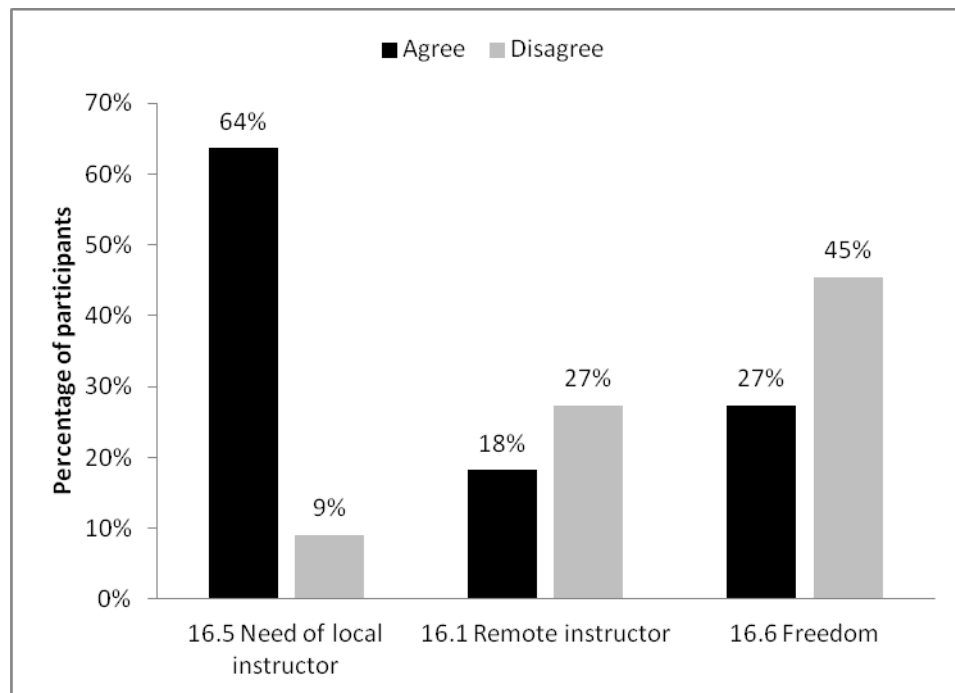


Figure 39. Participants opinions on availability of remote and local instructor.

The majority of 7 participants (64%) from 11 participants agreed on the need for local instructors in the remote access laboratory, while only 1 (9%) participant disagreed. On the other hand, more participants disagreed about the effectiveness of the instructor providing assistance remotely instead of locally. More specifically, 3 (27%) of the 11 participants disliked remote assistance, only 2 participants (18%) liked it, and the majority of 6 (55%) participants did not want to express their opinion.

Whilst focusing on working independently, a minority, 5 (45%) of the 11 participants, did not enjoy the freedom they had without supervision from local instructors. A slightly smaller minority, 3 (27%) of 11 participants, did agree that they preferred to proceed without local supervision.

Participants also responded to these questions by giving reasons to support their belief in the necessity of local or remote instructors in the remote access laboratory (see Table 18). Not all participants chose to give their opinion. The majority of comments, 5 of 6

comments, believed in the need for local instructors more strongly than in the need for remote instructors.

A number of comments demonstrated the necessity for local instructors because of their ability to support the class and also to answer students' enquiries. Comments such as "...*It is very necessary to have a local instructor conducting and looking after the class during the laboratory time...*" and "...*because I cannot ask all of my questions to the remote instructor...*" showed that students were expecting assistance from local instructors. Further disadvantages of providing only remote instructors in the laboratory were also presented. Comments such as "...*We need a local instructor to stay with us, as the remote instructor may not be able to rectify any usage problem on time...*" identified the potential problem of delayed communication between remote instructors and students.

Some comments may indicate an extra responsibility for remote instructors. More specifically, remote instructors were less likely to be able to control the attention of students in the class. Comments such as "*The remote instructors may have some difficulty to control the local student to pay attention to the class...*" illustrated this point.

Furthermore, there was an extra concern from the participants regarding the use of language. Participants gave a comment like "*I would like to have the local instructor conducting the entire remote lab using Thai language... I had learning difficulty...*" which showed a problem of English communication with Thai students. Although the workshop was conducted by the author who is a Thai native, there was some technical material that was only written in English.

The only positive comment, that preferred remote instructors to the local instructor, was related to the participants' independent working style. Participants may feel more stress and less freedom while having local instructor watching them. A comment "*I may feel tenser by having local instructors when I'm accessing a remote lab*" illustrated this point.

Table 18. Supporting reasons from participants regarding their need of local or remote instructors.

Position	Combine Q16, 17, 18
Local Instructors	We need a local instructor to stay with us, as the remote instructor may not be able to rectify any usage problem on time. It is very important because the local instructor can guide me in the lab.
	The remote instructors may have some difficulty to control the local student to pay attention to the class. Remote instructors are not necessary as it was already good with our local instructors.
	Because the laboratory should have an attention of local instructors at all time. It is very necessary to have a local instructor conducting and looking after the class during the laboratory time. It would be great if the remote laboratory could also open 24 hours. However, I don't believe that the students will have a 24 hours access.
	I need the local instructor because I cannot ask all of my questions to the remote instructor. The rest of the question I could get an answer from the local instructor.
	I would like to have the local instructor conducting the entire remote lab using Thai language. Also, I would like to use the remote access laboratory more than the current availability. I had difficulty learning in a remote lab.
Remote Instructor	It is not necessary to have a local instructor. I may feel tenser by having local instructors when I'm accessing a remote lab.

5.3.6.1 Discussion

These findings indicated that the Thai students relied on the presence of local instructors more than remote instructors. It confirms a point made by Gulatee and Combes (2008) that tutor support is extremely necessary to students studying online. Although the remote instructor in this study was available via real-time synchronous communication, students preferred to interact with local instructors.

Sivakumar (2004) believed that delivering lectures via interactive video should not change the appreciation of the learning process by students, compared with the traditional face-to-face instruction. However, results from this study showed that providing only a remote instructor in a laboratory may not be sufficient, as students may need more guidance during hands-on sessions. Furthermore, an extra duty, class controlling, of instructors within Thai setting was shown. This was as a specific issue of the Thai learning style, which is group learning (Selvarajah, Chelliah, Meyer, Pio, &

Anurit, 2010). The less independent learning style of Thai students also appeared in this study and confirmed Selvarajah's concerns.

5.3.7 Possible improvement of the remote access laboratory

This section analyses data from the questionnaire which asked about improvements which should be made to the remote access laboratory. A number of enhanced features were discussed with the participants but could not be implemented in the remote access laboratory provided to them. The participants voiced their opinions on the following, not yet implemented, features:

- Ability to save an ongoing configuration to allow a continuation in a future session
- A clickable device icon in the GUI to gain direct access to the equipment
- Availability of the remote access laboratory on a 24/7 basis
- A booking system for reserving equipment in the remote access laboratory

Participants' responses to these features are presented as an agreement percentage (see Figure 40). The most convenient feature that participants agreed would be desirable was the ability to save configurations in order to continue working with the equipment in future sessions. Nine (82%) of the 11 participants felt it would be more convenient to be able to save their configuration so that they could return to the laboratory in future and continue their practice. No participant disagreed with the need for this feature.

The second most popular feature agreed upon was about a small change to the user interface of the remote access laboratory. Seven (64%) of the 11 participants felt it would be more convenient if the GUI could have a clickable device icon for gaining direct access to the equipment. Again, no participant disagreed about this possible feature.

In addition, the third enhancement was about the availability of the remote access laboratory. Seven (64%) of the 11 participants felt it would be more convenient if the laboratory could provide a 24/7 service. However, 1 (9%) participant disagreed.

The last feature was about making reservations for using the remote access laboratory. Seven (64%) of the 11 participants agreed that it would be more convenient if the

laboratory could have a dedicated booking system. However, 2 (18%) participants disagreed about the need for this feature.

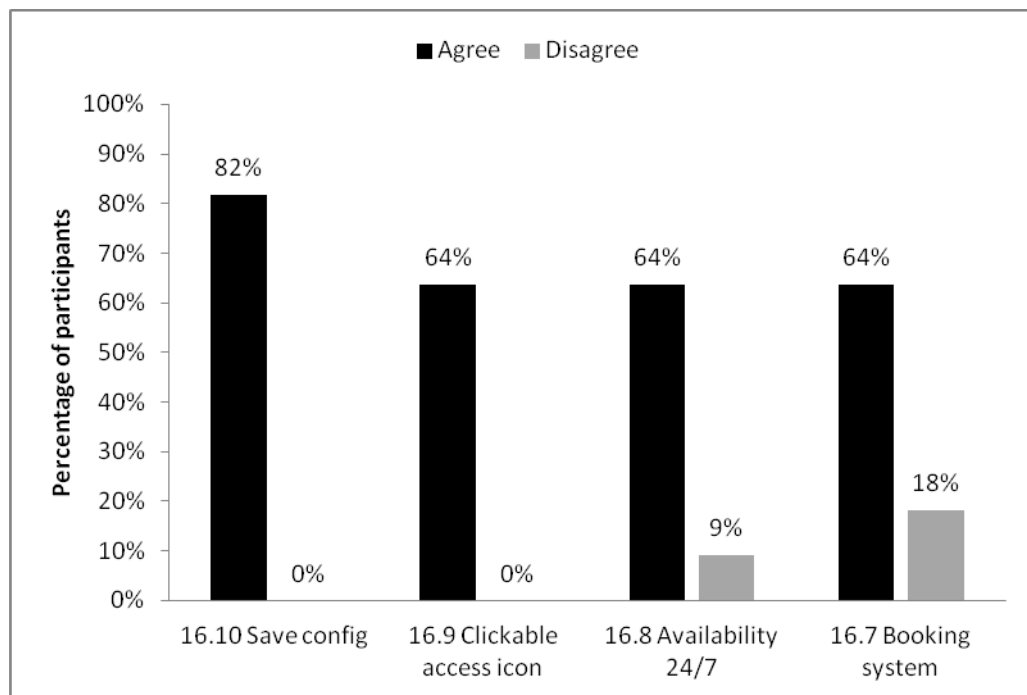


Figure 40. Participants' response to the different enhanced features that could be built in the remote access laboratory.

Additionally, the participants suggested other facilities that should be available in a remote classroom (see Table 19). These suggestions mentioned a need to be able to contact an instructor, both locally and remotely. The participants also wanted to have more time using the remote access laboratory. Further suggestions also mentioned the need to be able to pre-select the topics of laboratory tasks, and even to request to view the physical setup of the equipment used in the remote laboratory. Displaying the physical setup may offer a better physical appreciation for the remote participants; however, as this also involves using limited workshop time, it could be counter-productive. Also, ongoing demonstrations of the interconnection of equipment may be prone to error, due to the instability of the remote connection. Remote students might become confused by the introduction of physical interconnection problems.

Table 19. Additional participants' suggestion of what should be available in a remote classroom.

Q15: Additional suggestion about facility that should be available in a remote classroom
Should have an instructor with us all the time. When we faced a problem or having a question, then we can ask the instructor immediately.
I would like to see a clear step process of interconnecting the equipment, before working in the lab.
Should provide in conjunction with a normal lecture, but emphasised on practical hands-on.
I think it could depend on the ability of the students. It would be great, If you could provide more communication channel and more suggestion in the lab.
Should be able to select the topic before the class.
Increase the available usage time, because not familiar.

5.4 An analysis of the evaluation result of using SMD application

The previous section described about the overall user experience of the remote access laboratory. This section will focus on the results of the participants' evaluations of SMD software. Participants had applied SMD software in the remote access environment.

5.4.1 *Preferable learning component in the remote access laboratory*

The remote access laboratory provided to participants in this research consisted of different learning components, namely: a text-based command line interface (CLI), a real-time video stream of the equipment via webcam, and SMD software. Participants were asked to evaluate different combinations of these learning components by giving a score from 1 to 5. Responses from the 11 participants were collected and calculated as mean and standard deviation score of each combination (see Figure 41).

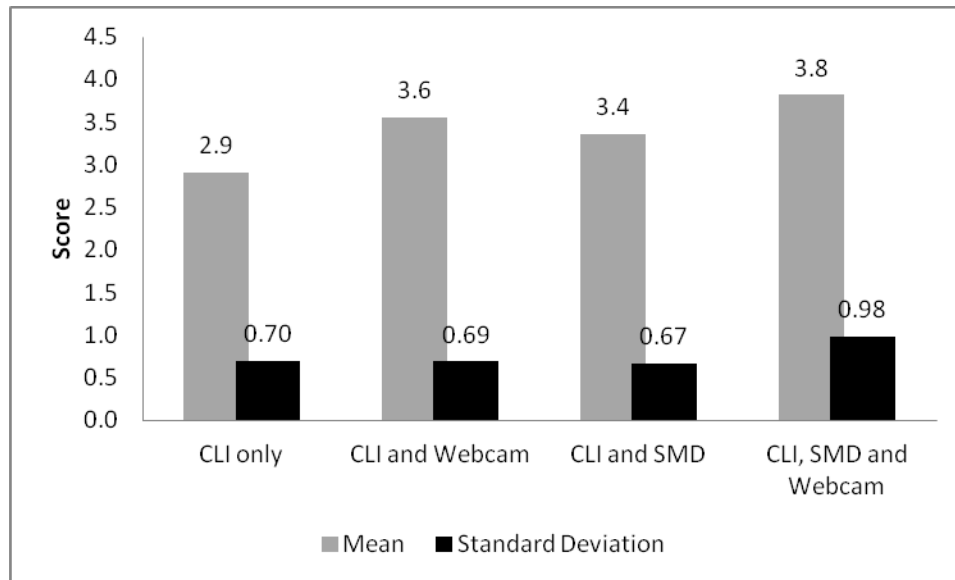


Figure 41. Mean score of different learning component combinations.

The highest mean score was when all components were available to the participants. The combination of CLI, SMD and webcam received the highest average score of 3.8 from the maximum of 5 points. On the other hand, the CLI learning component alone has only 2.9 mean score which was the lowest mean of all combinations.

Further the other two combinations of CLI with webcam or SMD were also available for the participants to evaluate. The combination of CLI and SMD received an average score of 3.4 from the maximum of 5 points, whereas the combination of CLI and a webcam received a slightly higher score, an average of 3.6 points.

The standard deviation (SD) value of each combination was also different. The CLI alone had an $SD = 0.70$. The combination of CLI and webcam had an $SD = 0.69$, while the combination of CLI and SMD had a slightly lower $SD = 0.67$. Finally, the combination of all learning components, CLI, SMD and webcam, had the highest $SD = 0.98$.

Three reasons from the participants all supported the combination of CLI, webcam and SMDs (see Table 20). Two reasons were related to the ability to view the various type of information at the same time. Comments illustrated this point were “...*I can find out other relevant information...*” and “*Seeing a complete view with every component will let me see the overall picture...*” Another comment illustrated that the combination of CLI, webcam and SMDs was helping the participants to understand. This comment was

“The combination of three components helps me for a better understanding in the learning process”.

Table 20. Support reasons of combination of CLI, webcam and SMDs.

Q19a
Because then I can find out other relevant information along with configuration
Seeing a complete view with every component will let me understand the overall picture more than any other combinations
The combination of three components helps me for a better understanding in the learning process

5.4.1.1 Discussion

Results indicated that the learning component of the CLI alone was not seen as adequate by students when they compared it to various combinations. The highest average value was on the combination which had the most components, CLI-SMD-webcam. This comparison of text-based CLI to graphic-based SMD and webcam meant, according to Prensky (2005), that the new generation students preferred to learn from graphic-based materials first, whereby: *“for today's Digital Natives, the relationship is almost completely reversed: the role of text is to elucidate something that was first experienced as an image (Prensky, 2005, p.100).”* However when it is compared to the average score of the combinations that had two components, the average score of the combination of CLI and webcam seems to be slightly more popular. This could mean that the students see the webcam as a more important component than SMD.

The standard deviation (SD) value of each choice of combinations could indicate the consistency of the scores received. There were two ranges of standard deviation values, lower (0.70) and higher (0.98). The higher value of SD indicated the higher distribution of the score. Within the lower range of SD, which showed more consistency and quality of the average score, the combination of CLI and webcam had the highest mean. Again, this could indicate that the students placed a higher value on being able to see the equipment. From education theorists' perspectives (Biggs & Collis, 1989; Bloom, et al., 1956; Piaget, 1952), physical equipment were closer to concrete learning than more abstract diagrams of SMDs. Hence these Thai students, unfamiliar with an online

learning environment, may feel more comfortable working with fundamental concrete learning elements.

5.4.2 Pedagogical advantages of SMDs

The evaluation of the pedagogical value of SMDs in the remote learning environment was conducted by the participants. Each contributed their opinion about each value. Eight pedagogical values were presented to the participants. They were:

1. Memorising course content
2. Visualising the network
3. Understanding without need of remembering CLI commands
4. Focusing on content
5. Retaining knowledge
6. Understanding
7. Encouragement
8. Device configuration

Responses of the 11 participants were collected and presented as percentage agreements. (see Figure 42).

The highest agreement percentage was on the retention value of the SMDs application. The majority of the participants, 7 (64%) of the 11 participants, agreed on the value of SMDs, which helped them to retain knowledge after classroom sessions. Only 1 participant (9%) disagreed with this value. The second highest agreement percentage was on the memorisation value. Six (55%) of the 11 participants agreed that the SMDs helped them to memorise the content of the course.

The third agreement percentage was on the value of understanding. Five (45%) of the 11 participants agreed that the SMDs helped them to understand the content of the laboratory. Only 1 participant (9%) disagreed with this statement. Similarly, the same number of 5 participants (45%) also agreed on SMDs' encouragement value. Those 5 participants believed that the SMDs could encourage them to learn. Again, 1 participant

(9%) disagreed. Finally, the same number of 5 participants (45%) were also agreed on the visualisation value of SMDs. However, 2 participants (18%) disagreed on the visualisation value of SMDs.

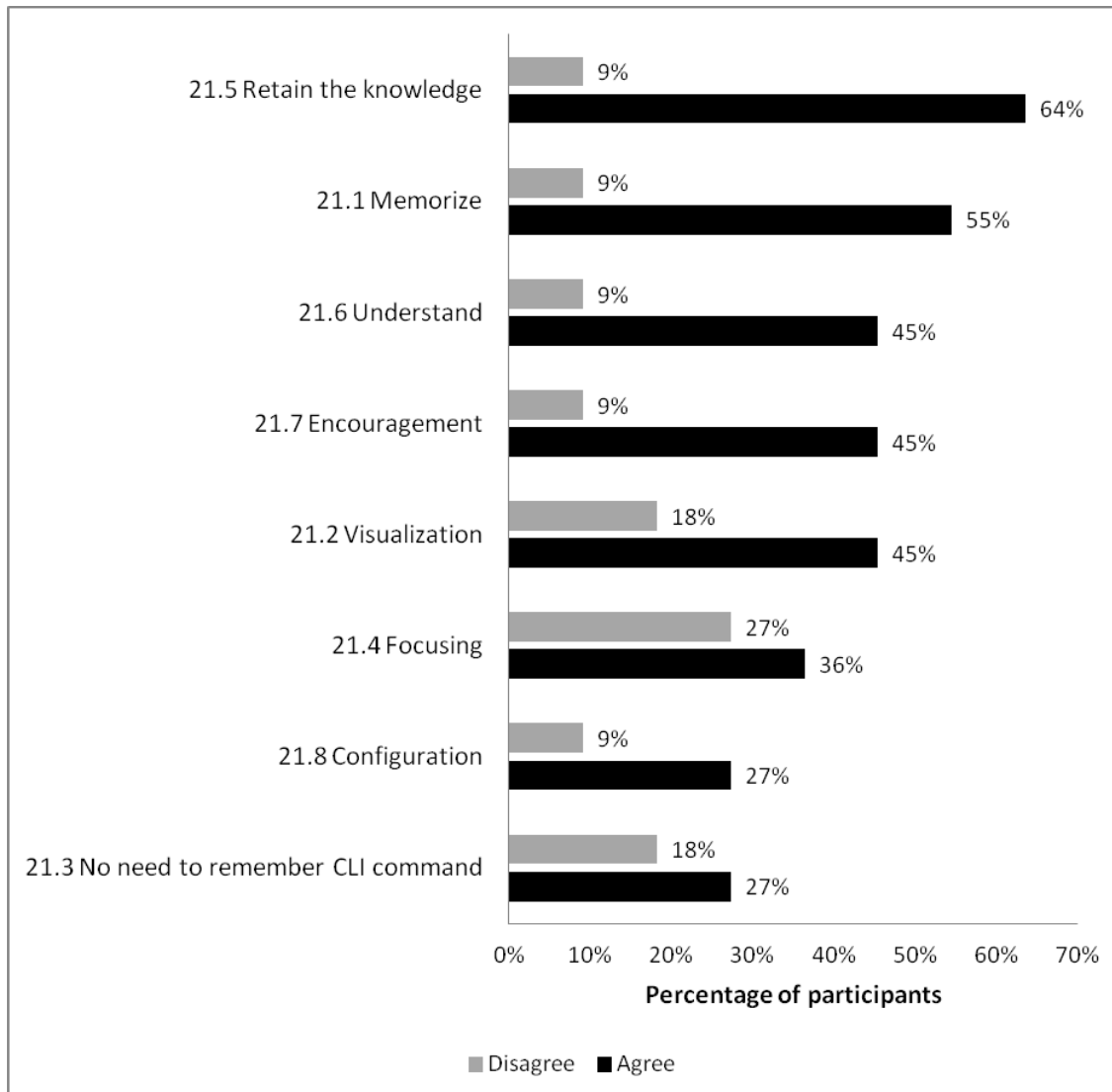


Figure 42. Percentage agreement from the participants on each pedagogical value of SMDs.

A small number, 4 (36%) of the 11 participants, agreed on the value of SMDs in helping them to focus on laboratory content. Four (36%) of the 11 participants remained neutral and 3 (27%) had an opposite belief. Similarly, the majority of the participants, 7 (64%) of the 11 participants, remained neutral when asked their opinion about whether the SMDs were helping them learn to configure network devices. Three participants (27%) agreed and 1 participant (9%) disagreed.

Finally, the majority, 6 (55%) of the 11 participants, neither agreed nor disagreed when asked whether it was necessary to remember CLI commands while using SMDs. Three participants (27%) agreed that SMDs helped with the learning process and thought that it was unnecessary to remember the CLI commands while using SMDs. On the other hand, 2 participants (18%) disagreed that SMDs help them, and said that they needed to remember CLI commands in order to learn.

There was one comment from the participants about the usage of SMDs. The participant suggested that *“the information on the diagram may be too short which make it is hard to understand”*. This demonstrated that the information provided in the diagram may not be entirely adequate for the participants.

5.4.3 Assistance of SMDs in the remote access environment

The inclusion of SMDs enhanced the users’ experience in the remote access environment in this study. The evaluation results from the participants, regarding their opinions about the assistance offered by the SMDs, specifically in the remote laboratory, are presented in this section. Responses were collected from the 11 participants (see Figure 43).

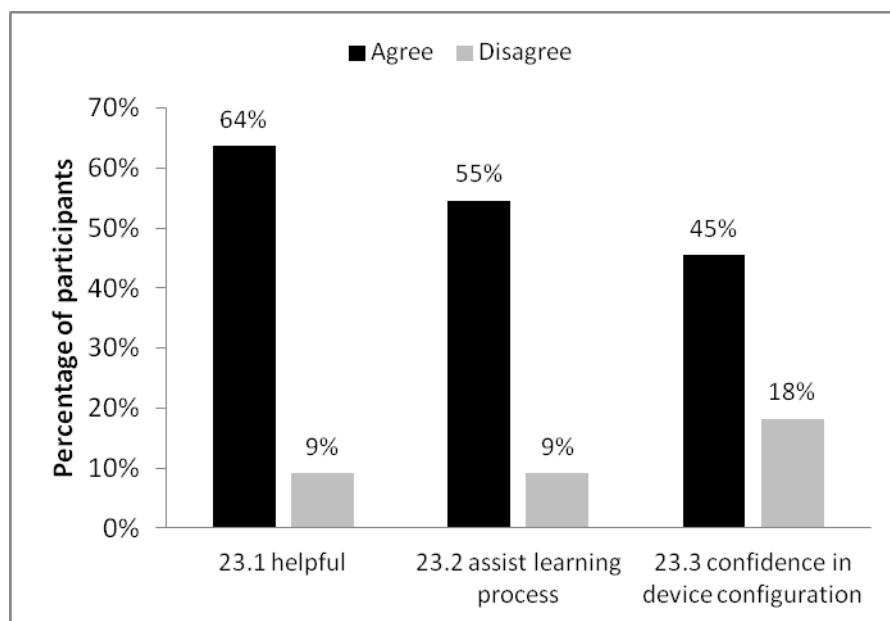


Figure 43. Participants’ agreement percentage on the assistance of SMDs in the remote learning environment

Overall, the majority of the participants, 7 (64%) of the 11 participants, agreed on the statement which said that the SMDs were helpful in assisting them to learn in the remote access laboratory. One participant (9%) disagreed and 3 participants (27%) did not express their opinion.

The majority, 6 (55%) of the 11 participants, also agreed that the SMDs assist their learning process in the remote access laboratory. Again, one participant (9%) disagreed. However, only 5 participants (45%) agreed that the SMDs help them to build their confidence in their ability to configure devices during the remote access laboratory. Four (36%) remained neutral and 2 (18%) entirely disagreed.

5.4.4 Improvements

The questionnaire also asked the participants about the ways in which SMDs might be improved. The following topics about improvements were available for the participants to express their opinion:

1. User interface of the SMDs application was easy for them to use.
2. Response of the SMDs application was fast enough.
3. An ability to modify network configuration directly from the SMDs application.

The participants responded to each statement and responses were collected as an agreement percentage (see Figure 44). There was a space for the participants to be able to express any further opinions as well.

Five (45%) of the 11 participants remained neutral on the statement focusing on the easiness of the SMD's user interface and speed of response. Two (18%) of the 11 participants disliked the current user interface and its response. On the other hand, 4 participants (36%) remained positive about the speed and user interface.

Six participants (55%), the majority, agreed on the suggestion that the SMDs software should allow them to modify the network configuration directly. Only 1 participant (9%) disagreed and 4 participants (36%) remained neutral.

Even though there was an extra space in the questionnaire for the participants to suggest their ideas on the improvement of the SMDs application, there was no direct comments from the participants.

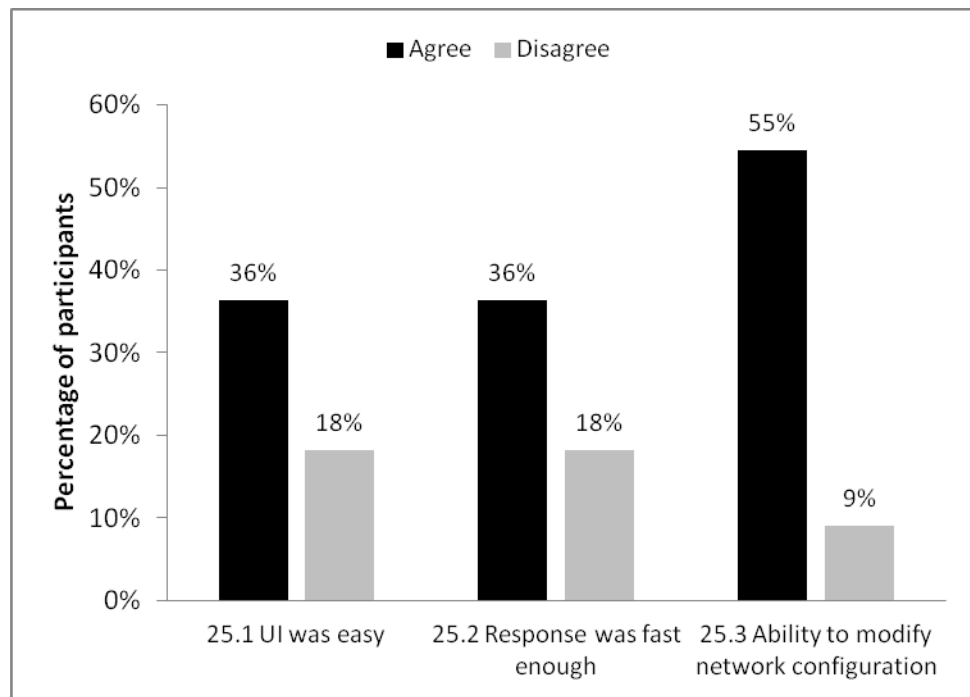


Figure 44. Participants' responses to the improvement of the SMDs application.

5.5 Summary

In summary, although findings from this study drew chiefly from a qualitative perspective with a small number of selected participants and may have a generalisation issue, they could be summarised as the following viewpoints.

- Limitation of the physical laboratory's usage time was the main dissatisfaction of students.
- Students preferred the traditional physical laboratory as a normal classroom-based teaching method, mainly because of the ability to interact with physical equipment.
- Students lack confidence in using the remote access laboratory mainly because:
 - Lack of familiarisation to the laboratory and online teaching style
 - Lack of physical interaction to equipment

- However, students had a positive feeling in using remote access laboratory as a supplementary self-practice facility and feel encouraged to learn in a self-conducted environment.
- Major advantage of using remote laboratory that students agreed was that the laboratory could be used to demonstrate an immediate practical example in a normal lecture room.
 - The need of showing a real-time video access to physical devices was felt as an important learning element from students' perspective.
- The main disadvantage of using remote laboratory from the students' perspective were that the laboratory was confusing to use, lack of familiarity, lack of physical interaction and slower response time.
- When universities use a remote laboratory as a main teaching tool, students may prefer more access to local instructors than remote instructors; mainly because:
 - Untimely response and limited availability of remote instructors
 - Remote instructors may lack extra responsibility of local instructors, particularly tied with the ability to control the class, which benefits the group learning style of Thai students
- The benefit of SMDs in remote access laboratory was mainly to help students maintain their knowledge and assist their learning process; however, the lack of familiarity and limited access time to the laboratory in this experiment prohibited the further usage of SMDs.
- In general, students complained about the slow response of the remote laboratory and suggested that the laboratory could provide further ability to modify the physical setting of network configuration.

CHAPTER 6 Non-technical skills building in internetworking education

6.1 Introduction

This chapter presents the results and analysis of the data obtained from a questionnaire designed to investigate non-technical skills building in internetworking education. The analysis has been organised into four sections, as outlined below.

1. Participants' backgrounds
2. An analysis of participants' opinions of non-technical skills development
3. An analysis of participants' self evaluations of their existing non-technical skills
4. An analysis of the sources of non-technical skills development.

To sum-up, the findings of non-technical skills building in internetworking education is presented in below. The details of each major findings are showed in the listed sections.

Table 21. Findings summary of non-technical skills building in internetworking education

No.	Findings	Section
1	Students believed that their current coursework helped them to build non-technical skills, but did not totally felt satisfied with the contribution amount.	6.3.1
2	Communication and team working skills were the top two skills that the students are expect to derive from a university's network courses.	6.3.2
3	Students were expecting that non-technical skills would be taught in project units, and would be more appreciate to be taught by a series of non-technical skills units than a single unit.	6.3.3
4	Learning non-technical skills through online and self-study modes were considered as the least favoured options.	6.3.3
5	Students saw university-based study as the secondary learning source of non-technical skills when compared to the primary sources of work experience and normal social activities.	6.5.1

Appendix F.1 contains a published preliminary report on the investigation of the opinions of a small number of participants (Makasiranondh, Maj, & Veal, 2011b). The questionnaire used to collect the data in this section can be found in an Appendix E.

6.2 Participants' backgrounds

6.2.1 Participants and their course enrolment

Participants in this research were students from the School of Computer and Security Science (SCSS) of Edith Cowan University (ECU). SCSS offers 50 courses in total which are related to computer and information technology. These courses are separated into 7 different categories, namely computer science, information technology, networking science, library technology, information services, computer security, and security science. They include all levels of education from bachelor, graduate certificate, graduate diploma, master and doctoral degrees, both research-based and by course-work. However, doctoral participants were not included in this study. (Detailed outlines of the courses may be found at <http://www.scss.ecu.edu.au/future/courses.php>). From the overall fifty courses, the data collection process involved students from eleven courses. Table 22 shows the distribution of the participants from different courses.

Table 22: Participants' course distribution

Courses	Code	Number of participants
Bachelor of Information Technology	U67	10
Bachelor of Computer Science	U65	7
Bachelor of Science (Networking Science)	K87	1
Bachelor of Computer and Network Security	K07	7
Graduate Certification in Network Technology	U38/V27	2
Master of Games and Simulation Programming	I47	2
Master of Network Technology	I38	18
Master of Science (Computer Science)	I39	1
Master of Computer Science	I45	11
Master of Information Technology	I46	4
Master of Computer and Network Security	I18	3
Total		66

The data collected in this study was based on only four from the seven categories of the SCSS courses. These courses have a significant component of networking and internetworking technology units. The four categories were grouped according to

similarities in the nature of their contents. These categories were Computer science practice (course codes U65, I39 and I45, I47), Network technology practice (K87, U38 and I38), Information technology practice (U67 and I46) and Computer security practice (K07 and I18). The total number of participants in this study was 66. Figure 45 describes the range of participants from the different course categories and levels of study.

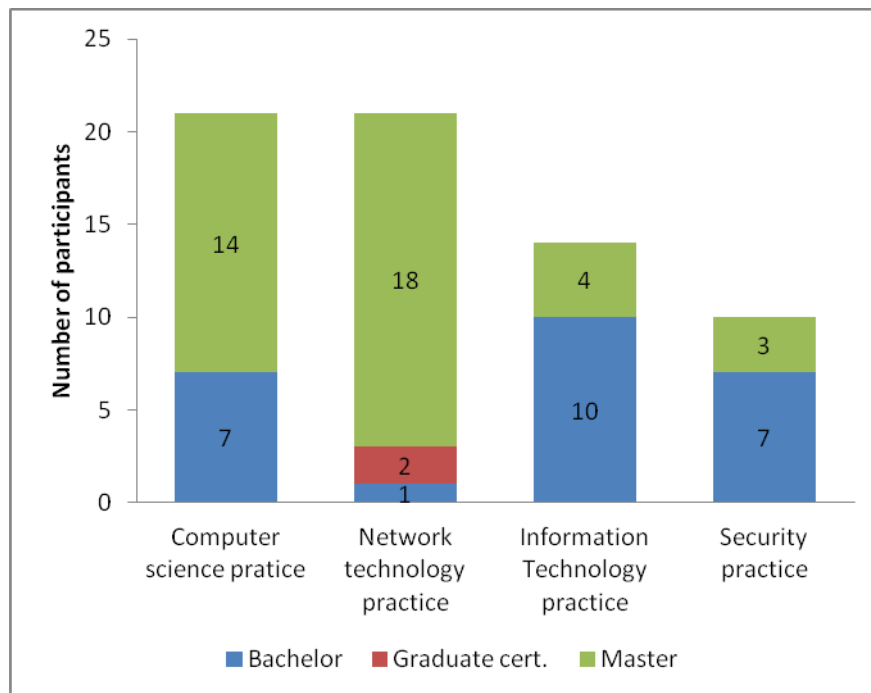


Figure 45 Distribution of the participants in courses

6.2.2 Non-technical skills units in the focused participants group

Of the eleven courses analysed in this study, eight courses were provided with dedicated non-technical skills units. The three courses, which did not include any dedicated non-technical skills in the course structure provided were the Graduate Certificate in Network Technology (U38), the Master of Games and Simulation Programming (I47) and Master of Computer and Network Security (I18). Graduate certificates were only one semester courses and time restriction challenging the incorporation of any dedicated non-technical units. Surprisingly, two Masters by coursework (I47 and I18) were not equipped with any non-technical skills units, while the other masters by coursework all included CSI5108 IT Professionalism and Practice in their curriculum. However, the school provide the training of non-technical skills in the other teaching units as embedded forms.

There are two common non-technical skills units offered by SCSS. These two units are CSG1132 Communicating in an IT Environment and CSI5108 IT Professionalism and Practice, which are early units in the undergraduate courses and the Masters courses respectively. CSG1132 was included in all Bachelor degree courses involved in this study as a first year compulsory unit and introduced the students to basic information and communication skills. For example, these skills include information searching, identification of information sources, and written and presentation skills in delivering information. This unit was essential to first year university students, especially for literature searches and written communication, which are the most important skills for university assignments (Barbara Combes, personal communication, 26 November, 2010).

CSI5108 IT Professionalism and Practice was designed for graduate level students. The contents were focused on building non-technical skills, knowing the environment of the IT profession such as ethical and legal issues, demonstrating knowledge of professional standards, and developing the necessary interpersonal and communication skills to operate effectively as an IT professional. The unit was conducted through a variety of activities such as group discussion, workshops, case studies and team-building activities.

6.2.3 Main internetworking technical skills units of the participants group

The courses involved in this study shared the same internetworking technology units, which could be included in a course structure as a core body of knowledge or as optional elective units. There were 11 main internetworking technology units, which had been divided into two separate areas as a Cisco-based internetworking technology specialisation and a networking specialisation.

The first area of specialisation was conducted according to industry certificates, in this case the Cisco Networking Academy program (CNAP). Therefore, the main teaching units were compatible with the Cisco Certified Network Associate (CCNA) and the Cisco Certified Network Professional (CCNP) certificates. The units were conducted at both undergraduate and graduate levels. These units were:

CCNA:

1. CSG1103/4103 Internetworking 1
2. CSG1104/4104 Internetworking 2

CCNP:

3. CSG2201/4201 Scalable Networks
4. CSG2202/4202 Multi-layer Switched Networks
5. CSG3201/4211 Remote Access Networks
6. CSG3302/4312 Internetwork Troubleshooting
7. CSG3204 Information Services Management.

Students wishing to complete the CCNP certification first had to complete the CCNA.

The second area of specialisation involved non-industry-based units. As an alternative to their industrial counterparts, these units were aimed at a senior year student of an undergraduate program or a student in a post-graduate program only. These units were:

1. CSG5106 Fundamentals of Computer and Network Technology
2. CSG5102 Internet Enabling Technologies
3. CSI5107 Network Security
4. CSG5206 Internet Technology and Management.

Therefore, students were able to select their secondary major as a specialisation in internetworking technology by enrolling in these units.

This research study also included courses that did not have a direct involvement with internetworking technology units, but they included units that were shared with internetworking students. The Master of Information Technology (I46) and the Master of Game and Simulation Programming (I47) courses were the only two courses that fell into this category. However, these two courses shared the same project-based units with internetworking students. Therefore, the feedback from these students was also included in the study results.

Project-based units are available across the board for students specialising in internetworking and other specialisation areas. All together, there were three project-based units available for enrolment. These three project-based units are:

1. CSI5150 Project Preparation
2. CSI5251 Project 1
3. CSI5252 Project 2

CSI5150 Project Preparation was one of the three units designed to help students clarify and refine their overall project ideas. The enrolling students have a chance to investigate an objective as well as planning and designing an allocated project. The scope and the nature of the project differed amongst the various student disciplines. The overall conduct of each project was supervised by a staff member with specific skills and experience in the students' areas of specialisation. Subsequently, CSI5251 Project 1 and CSI5252 Project 2 were focused upon the implementation and execution phases of the project itself. On completion of CSI5251 and CSI5252, students are required to present their results in a written report and make a final presentation to a panel of lecturing staff and students.

6.2.4 ECU's graduate attributes and units' graduate attributes

One way of emphasising non-technical skills in IT education is by defining the universities' expectations of the attributes which graduates will attain during their courses. A number of institutions in Australia have defined graduate attributes within their units and courses to address non-technical skills; however, the question remained whether the teaching approaches used in the universities were effective in attaining these (Barrie, 2005, p.1). Therefore it depended on universities' individual implementations to address non-technical skills teaching.

Australia-wide, generic graduate attributes include problem solving, critical thinking, interpersonal understanding and written communication skills. Before 2008, ECU had adopted ten graduate attributes:

1. Enterprise, initiative and creativity
2. Professional knowledge
3. Service
4. Workplace experience and applied competencies
5. Awareness of political, social and ethical issues
6. Communication
7. Internationalisation or Cross cultural awareness
8. Problem solving and decision making
9. Teamwork
10. Use of technology and information literacy

These have since been refined to five graduate attributes (Edith Cowan University, 2008). It was then decided to develop the following five graduate attributes in the technical skills units and project-based units. The current (2008) scheme of graduate attributes and some specific examples are included in Table 23 below.

Table 23. ECU graduate attributes (Edith Cowan University, 2008).

ECU's graduate attributes	Exemplified definition
1. Ability to communicate	Ability to clearly express their opinion in both written and spoken form by the usage of suitable technology
2. Ability to work in teams	Ability to work effectively by collaboration and contribution to teams of various forms
3. Critical appraisal skills	Other necessary workplace skills, such as making plans, organisation, problem solving and decision making
4. Ability to generate ideas	Ability to create and introduce a new idea with confidence
5. Cross-cultural and international outlook	Positively work harmoniously with different cultures and/or ethnic groups

The mapping between ECU's former attributes and the newer attributes is shown in

Table 24. The 5 new graduate attributes were designed to cover all aspects of the previous graduate attributes.

Table 24. The mapping between ECU's pre 2008 and the current graduate attributes (Edith Cowan University, 2008).

Previous attributes	New attributes
1. Enterprise, initiative and creativity	4. Ability to generate ideas
2. Professional knowledge	3. Critical appraisal skills
3. Service	2. Ability to work in teams
4. Work experience and applied competencies	3. Critical appraisal skills
5. Awareness of political, social and ethical issues	3. Critical appraisal skills
6. Communication	1. Ability to communicate
7. Internationalisation/Cross cultural awareness	5. Cross-cultural and international outlook
8. Problem solving /Decision making	3. Critical appraisal skills
9. Teamwork	2. Ability to work in teams
10. Use of technology/Information literacy	3. Critical appraisal skills

All units available at ECU include statements about the graduate attributes that are to be emphasised during the teaching process, but there is nothing in the course outlines that specifically addresses how these should be taught.

6.2.5 Distribution of the questionnaire

Amongst the 11 internetworking units, the questionnaire was distributed at the end of semester 1, 2010 and at the end of semester 2, 2010 to the following classes:

1. CSG1103 Internetworking 1 (Undergraduate)
2. CSG4103 Internetworking 1 (Post-graduate)
3. CSG2201 Scalable Networks (Undergraduate)
4. CSG4201 Scalable Networks (Post-graduate)
5. CSG2202 Multi-layer Switched Networks (Undergraduate)
6. CSG4202 Multi-layer Switched Networks (Post-graduate)

These units were part of the main internetworking technology area of specialisation. However, the questionnaire was also distributed to other more general units in which Internetworking Technology Masters students were enrolled in their final year namely:

1. CSI5150 Project Preparation
2. CSI5251 Project 1
3. CSI5252 Project 2

6.2.6 Age and work experience

The participants' age range was between 19 and early 40s. For the purpose of analysis the participants were divided into three age groups, namely 19-22, 23-26 and 27 and over years of age. Figure 46 shows the details of the age distribution of the participants.

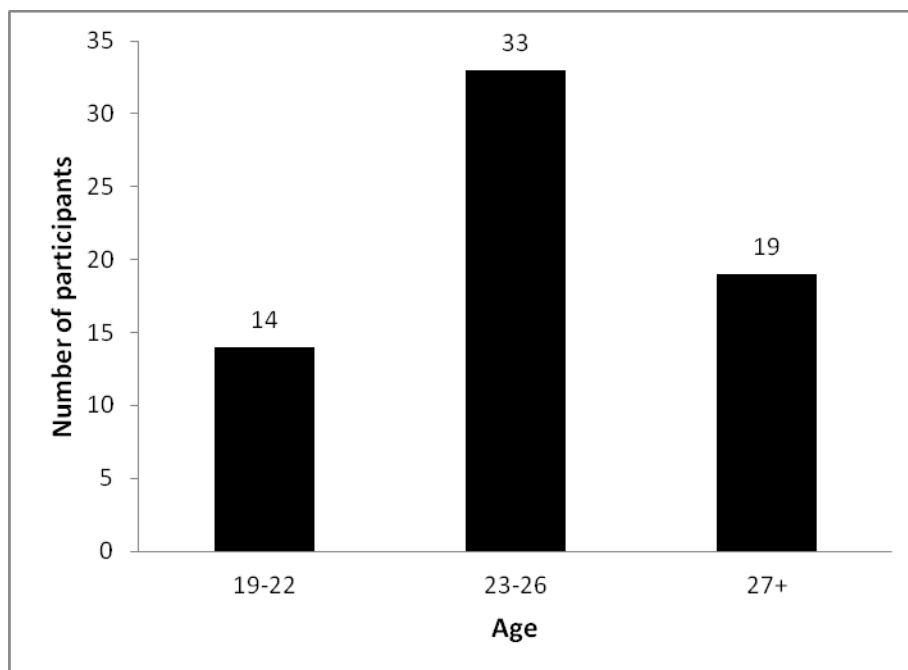


Figure 46 Age distribution of the participants

When the participants were asked about their working experience, only 41 respondents (62%) replied that they have been employed (Figure 47). Moreover, only 35 respondents (53%) classified their work experience as being related to the IT field.

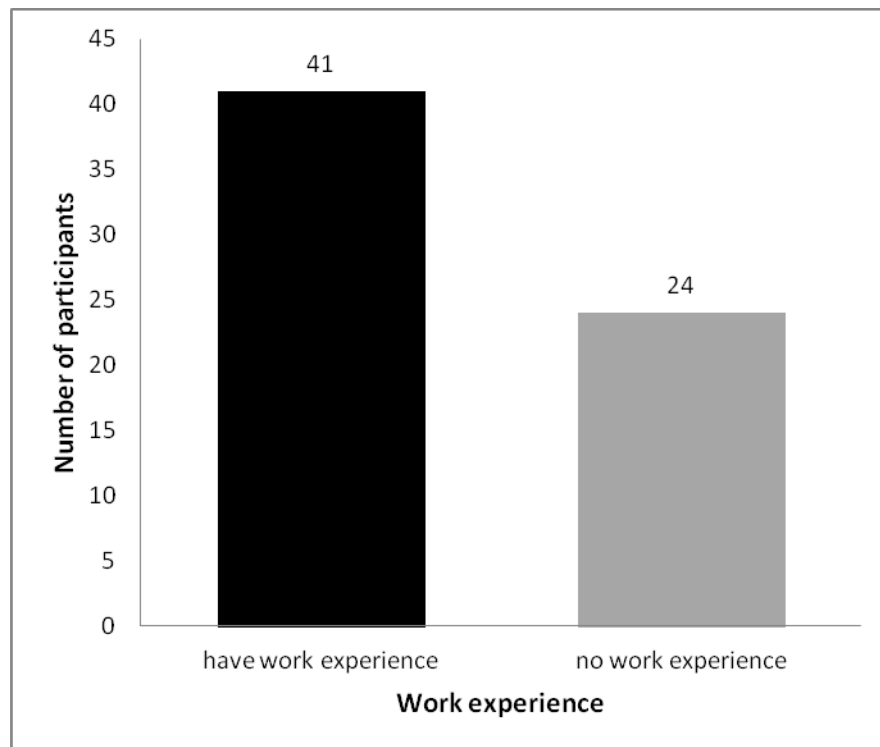


Figure 47. Previous work experiences of the respondents

When the researcher related the two questions and analysed the distribution of the participants regarding their age and their work experience, the results shown in Figure 48 were surprising. Two participant age groups, those under 23 years over 27 years old, formed a majority of those who identified themselves as students with previous work experience. The participant group aged between 23 and 26 years had the majority of non-experienced students. Furthermore, as noted in Figure 46, this age group, 23-26, also included the majority of participants in this survey. It was contrary to the researcher's expectations that the youngest group included a higher proportion of participants with work experience than the two older groups.

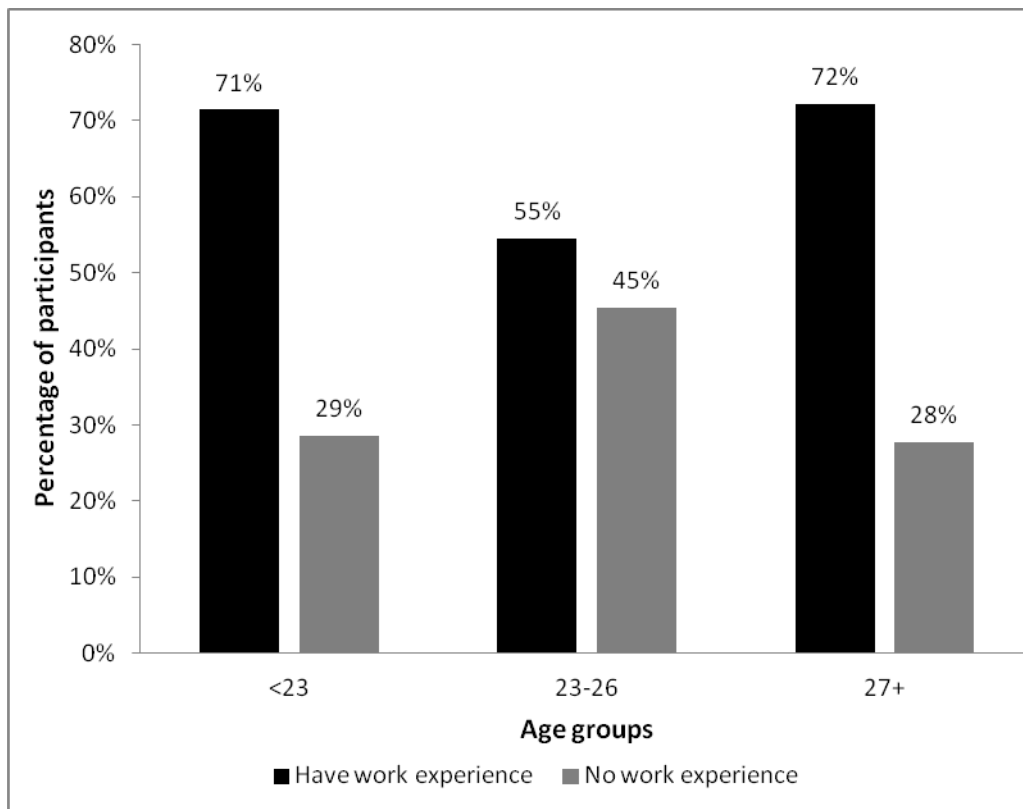


Figure 48 Work experience distribution of three age groups

6.2.7 Summary

There are two major student groups in this study of non-technical skills, each with similar numbers of participants. These two groups are computer science practice students and network technology practice students. Participants are mainly in their 20s with a larger group between 23 and 26. This larger group of participants has fewer experienced students.

6.3 An analysis of participants' opinions of non-technical skills development

This section presents the results from a questionnaire that asked the participants' opinions about non-technical skills development. The results were drawn from 10 questions from the questionnaire (see Appendix E). The results from these 10 questions can be grouped into 4 different topics as below:

1. The value of non-technical skills in the participants' courses.
2. The employers' expectations of non-technical skills.
3. University teaching of non-technical skills.
4. Opinions about communication skills.

This analysis will specifically discuss the responses to the questions asked about each particular topic. The results will generally refer to the number of participants' responses to each statement and for ease of comparison the results will frequently be converted to percentages.

6.3.1 Value of non-technical skills in the participants' courses

This sub-section presents an analysis of the responses from the questions that asked the participants to evaluate the value of non-technical skills in their courses.

Question 15 was *“Do you feel that the current course that you are undertaking builds your soft skills?”*

Question 15 asked the participants about their opinion of the effectiveness of the course in which they were currently enrolled for building their non-technical skills. Overall, a majority of participants (60%) agreed that their current course helped them to build their non-technical skills (Figure 49). When further divided into separate groups according to their course, the data indicated a similar trend. In every major course, students positively agreed about the value of non-technical skills to their course. Network technology students were more appreciative (67%), whereas Information technology students were less positive (50%). Figure 50 describes the detailed figures of percentage agreement of the value of non-technical skills in their current course-work.

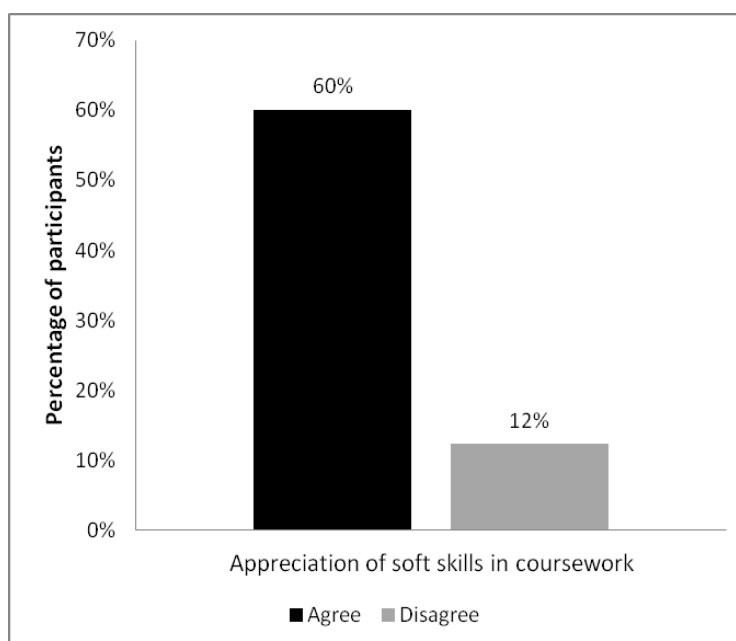


Figure 49. Overall percentage of participants' response of the current course-work appreciation of building non-technical skills.

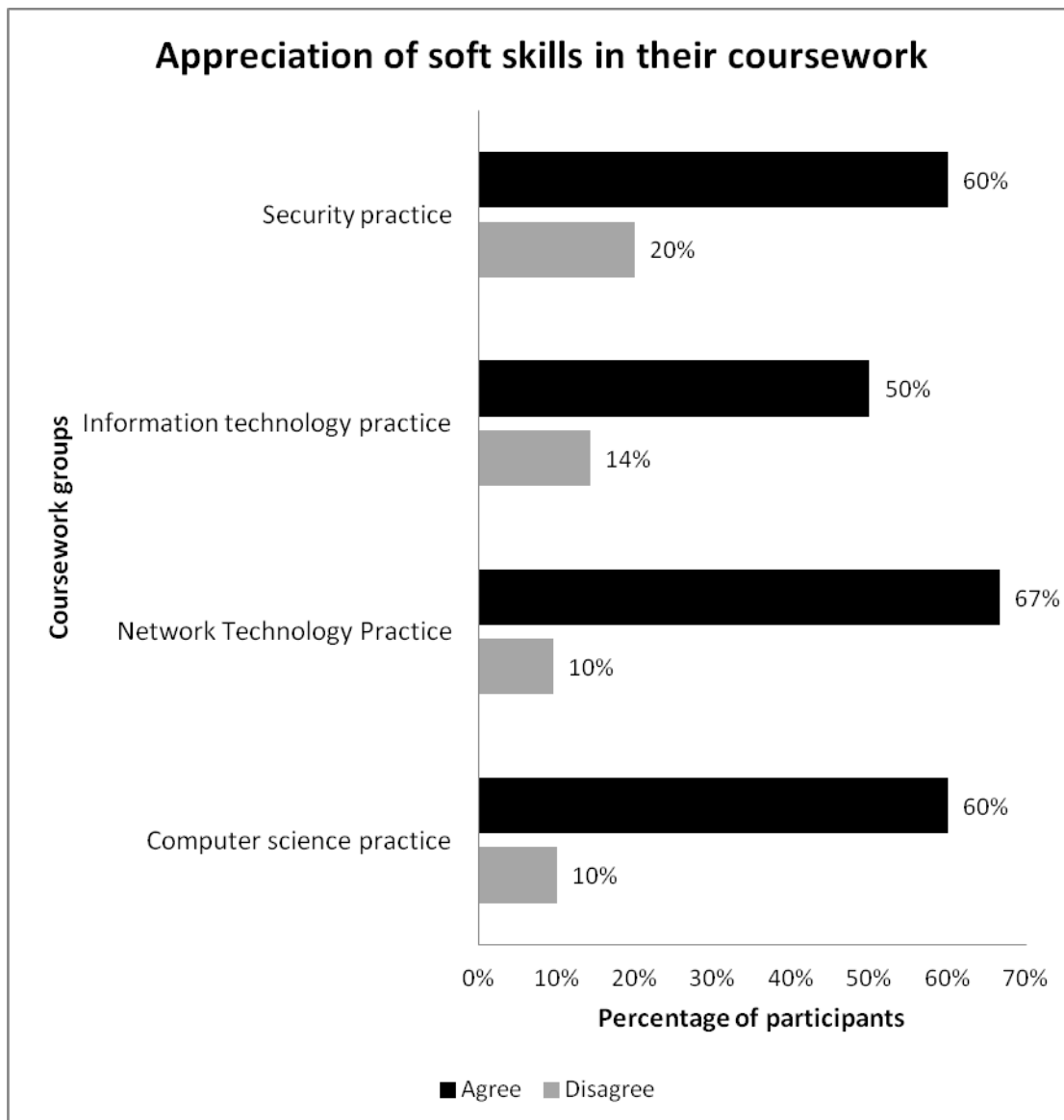


Figure 50. Percentage agreement of the current course-work appreciation of building non-technical skills, separated by their course groups.

A further investigation was made through the next question in the survey about the percentage of the coursework the participants believed contributed to their non-technical skills.

Question 20 was “*What percentage of the current coursework in which you are enrolled contributed to building your soft skills?*”

Question 20 asked students’ opinions and offered them a choice in which the percentages were divided into 5 ranges from 0%-100%. The total number of people participating in this question was 66. Table 25 shows the number of participants agreeing on each percentage range, grouped by their course code. Figure 51 uses the

same criteria as in section 6.2.1 to group the participants into four categories and hence is presented as percentages to allow comparison between the various groups.

The majority of computer science students, 12 participants (57%), weighed the value of their current course as 40%-59% or around half of the overall contribution to their non-technical skills development.

Surprisingly, the highest percentage (67%) of students who agreed that their current coursework contributed to their non-technical skills development, were network technology students (see also results from question 15, in Figure 50). Two percentage ranges, 20%-39% and 40%-59%, each with 8 participants (38%) were weighed equally within the group. Only 5 participants (24%) of Network Technology students weighed the value of course contribution over 60%. The proportion of highly appreciative students in the network technology group was, in fact, the lowest percentage of all the student groups. This finding could indicate that the current contents and activities in the curriculum which challenge the building of non-technical skills were less than half of the overall. Students may wish to be exposed more to the non-technical skills building activities in the Network Technology course.

It was not possible to develop a clear picture of the opinions of the majority of the Information Technology students about the percentage of non-technical skills in their university course. Virtually equal numbers of participants could be found in all percentage ranges, 3 to 4 participants (21% to 29%), except in the highest range of 80%-100% value. However, the information technology student group was the only group that believed their course demonstrated the lowest rate of contribution to their non-technical skills development (0%-19% range). Seven participants (50%) agreed that the current contribution was lower than half of the overall contents.

On the other hand, only 5 Security students (50%) agreed in the range of 60% and more contribution value. Although the number of participants in this group was lower than the number of participants in the other groups, the higher percentage value revealed the satisfaction of Security students with their non-technical skills building experiences offered by their course.

Table 25: Number of participants in each course code agreement on the percentage of their current coursework of building their non-technical skills.

Course	What percentages of the current coursework in which you are enrolled contribute to building your soft skills?					
	0-19%	20-39%	40-59%	60-79%	80-100%	Total
Bachelor of Information Technology (U67)	2	4	1	3	0	10
Bachelor of Computer Science (U65)	0	2	4	1	0	7
Bachelor of Science (Networking Science) (K87)	0	0	0	0	1	1
Graduate Certification in Network Technology (U38 or V27)	0	1	0	1	0	2
Master of Games and Simulation Programming (I47)	0	0	2	0	0	2
Master of Network Technology (I38)	0	7	8	3	0	18
Master of Science (Computer Science) (I39)	0	0	0	1	0	1
Master of Computer Science (I45)	0	2	6	3	0	11
Master of Information Technology (I46)	1	0	2	1	0	4
Bachelor of Computer and Network Security (K07)	0	2	2	2	1	7
Master of Computer and Network Security (I18)	0	0	1	2	0	3
Total	3	18	26	17	2	66

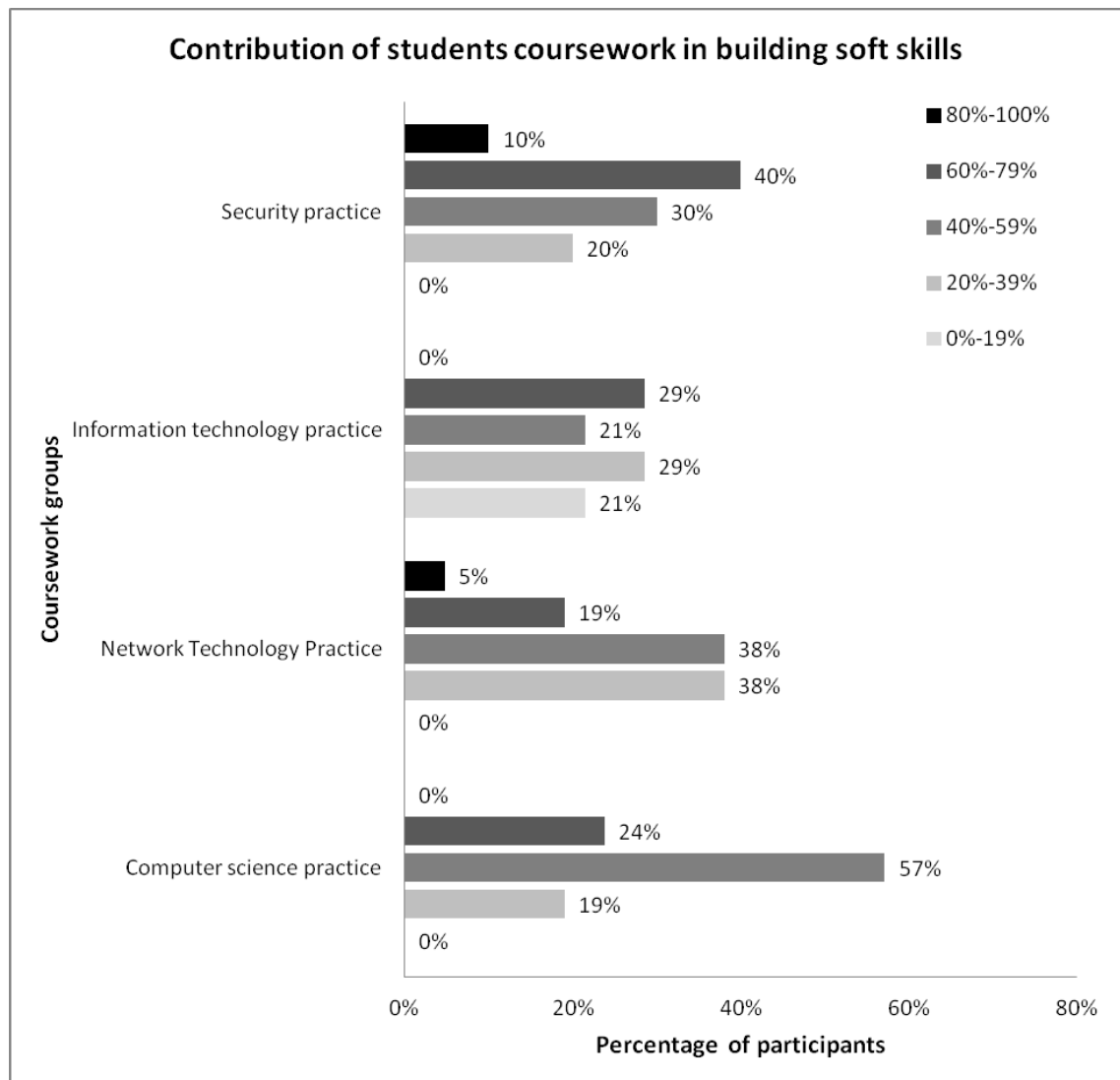


Figure 51. Percentage of students opinion on the percentage range of their current coursework in which contribute to build their non-technical skills, grouped by similarity of the course.

Question 21, *“Do you think that the current portion of soft skills teaching is enough for you to build your soft skills?”*

Question 21 asked the participants to rate their opinions on a five point scale. There were 66 participants who responded to this question. These participants were divided into four course categories in the same way as the previous analysis. Figure 52 shows the number of participants agreeing on each five point scale. Figure 53 presents the percentage agreement and disagreement of each course category.

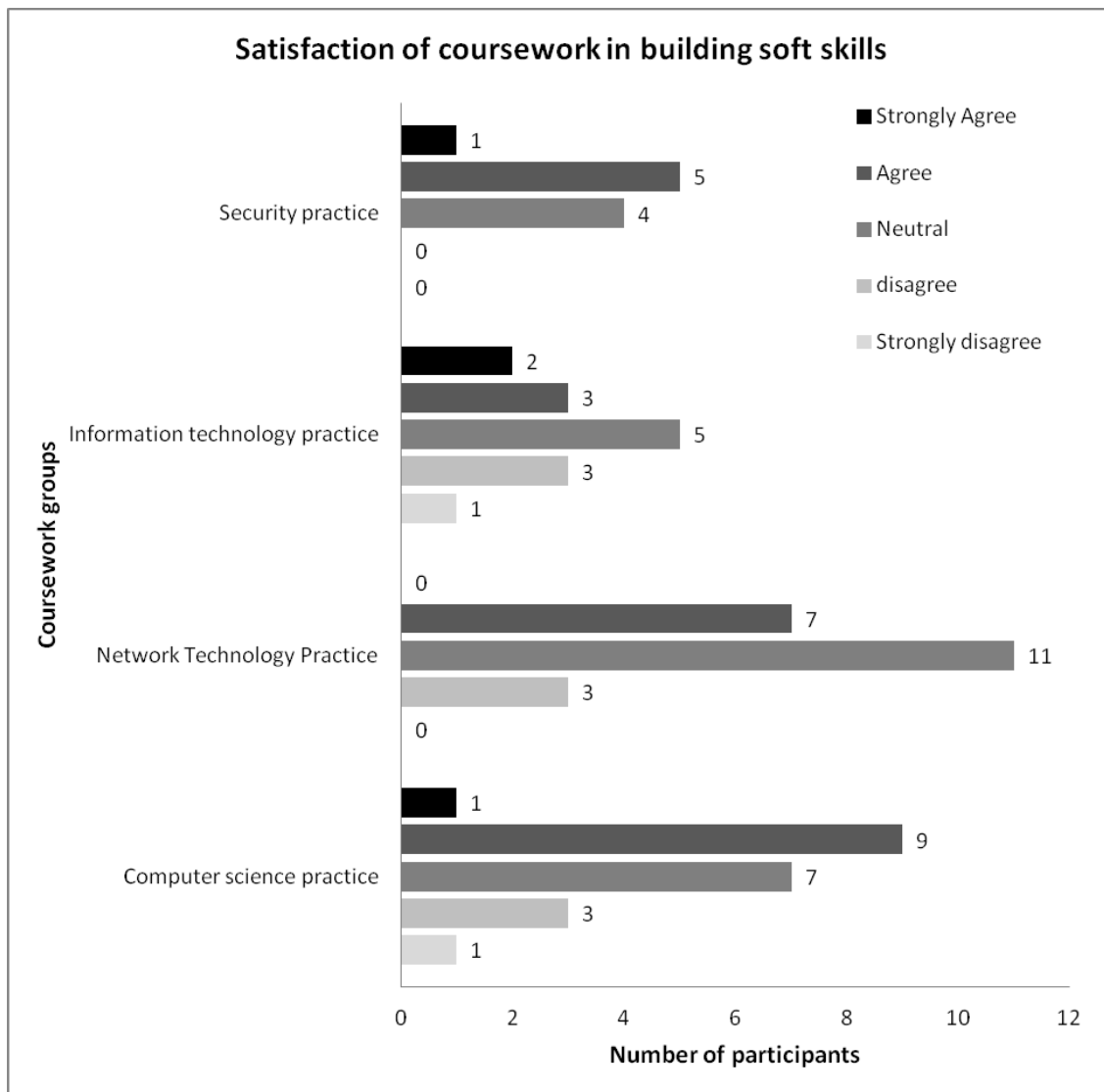


Figure 52. Number of participants agreed on the five point scale of their satisfaction of the current amount of non-technical skills building experiences in their curricula.

Out of 21 only 10 (48%) computer science students agreed that the current ratio of non-technical skills emphasised in their curricula was adequate (Figure 53). From previous analysis, the majority of students thought that the current ratio of non-technical skills embedded in their curricula was around half of the overall contents. This finding supports the inference that the students believed that the current ratio was sufficient.

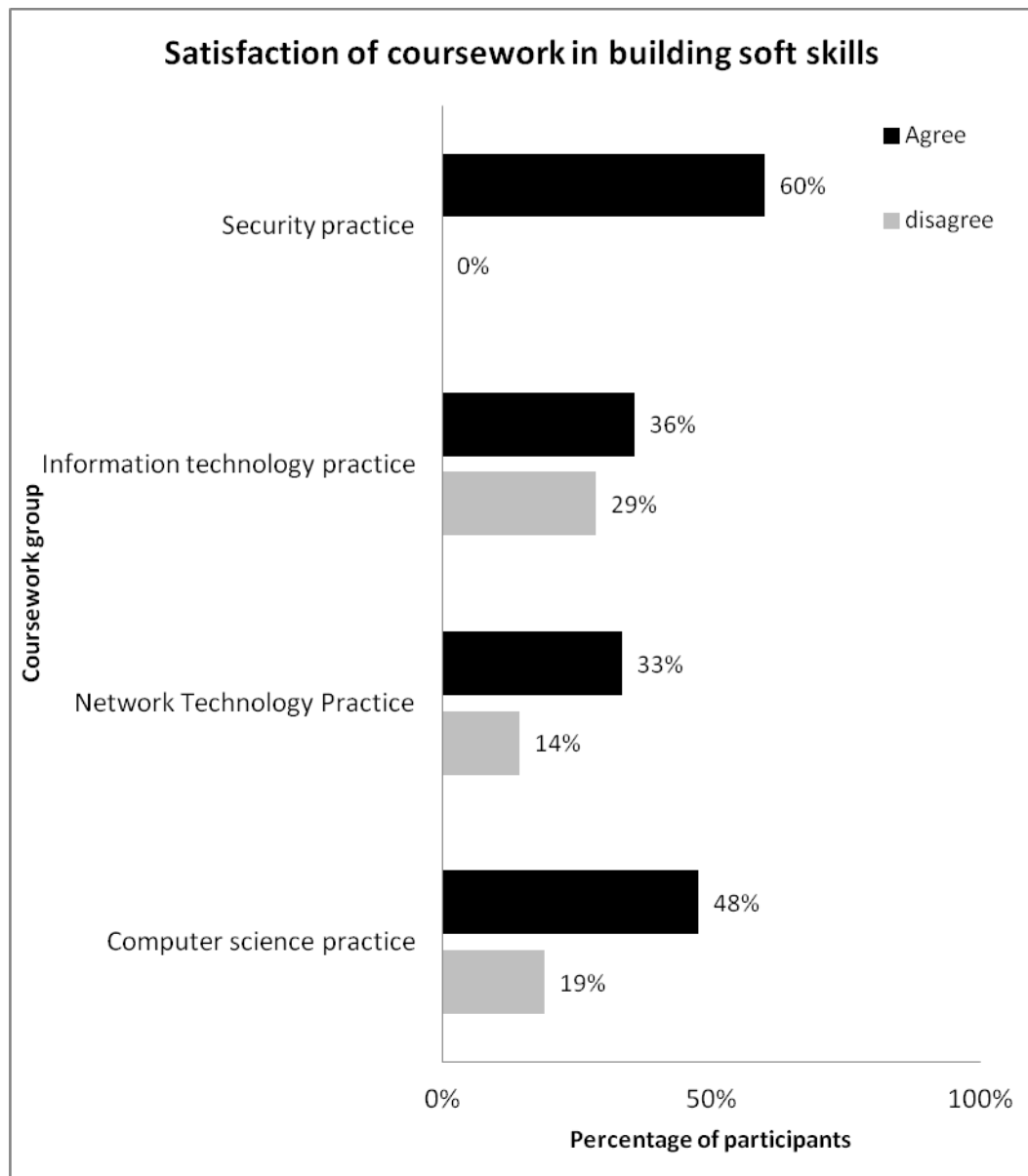


Figure 53. Percentage agreement/disagreement of the participants on their satisfaction of the current amount of non-technical skills building experiences in their curricula.

Only 7 (33%) network technology students agreed on the adequacy of the amount of non-technical skills in their curriculum. Their responses to question 20 showed that only 20%-59% of their course contents related to non-technical skills. This could indicate a stronger demand from the network technology students for more opportunities to develop their non-technical skills within their courses.

Further, there were 6 (60%) security students satisfied with the current non-technical skills building in their curriculum. From the questionnaire the majority of this student group thought that their non-technical skills development opportunities during the

course work comprised more than 60% of the overall contents. Further analysis is needed to identify the individual differences between non-technical skills development activities in units offered in the course.

On the other hand, there was not sufficiently distinctive data for the information technology students to be analysed. Participants in this group virtually equally agreed and disagreed on the adequacy of the non-technical skills development in their course. Therefore an analysis of this particular group is omitted.

6.3.2 Participants' opinions of employers' expectations of non-technical skills

Question 22 asked the participants to distinguish between technical and non-technical skills from an employers' perspective as if they were the employers.

Question 22, *“What percentage of soft skills do you expect from new employees compared with their technical skills?”*

The question offered choices of a 5 percentage scale range, similar to that used in question 20, from 0%-100%. The total number of participants who responded to this question was 65 students. Figure 54 shows the numbers of the participants in each of the course categories. The majority of Computer Science and Information Technology students, 14(67%) and 9(64%) students respectively, agreed that the non-technical skills in employers' perspective might be valued around 40%-50% or roughly the same weight as technical skills. On the other hand, the majority of Network Technology and Security students, 11(55%) and 4(40%) students respectively, valued non-technical skills more when comparing them with technical skills (60%-79% range).

Referring to the analysis of the former section, only 33% of Network Technology students feel satisfied with the current level of non-technical skills development in their course. The results from this section could indicate that this lower satisfaction rate could be due to the students' belief that the employers have higher expectations of the non-technical skills offered by new graduates as potential employees. A further investigation of the reasons for the different perceptions of the Network Technology students is needed.

Of note, in Network Technology project units, guest speakers from industry were frequently invited. A number of guests spoke about their backgrounds, the responsibility in their roles, routine duties, and their personal contributions to the company in which

they were employed. Regularly, Network Technology students asked about the job availability in the market and frequently asked about employment opportunities and the application process. Guest speakers mentioned specific technical skills required for their roles and also often highlighted the value of non-technical skills. The guest speakers may be the main reason which differentiates the Network Technology students' opinions from those of other course groups; however, a confirmation by further study is needed. Invitation of guest speakers were one of the solutions suggested by ACS as an alternative way of introducing near-industry experiences to the university-based curriculum (ACS, 2008, p. 6). Benamati and Mahaney (2007) also mentioned that the value of non-technical skills in many cases surpasses the value of technical skills when in the context of choosing the right candidates.

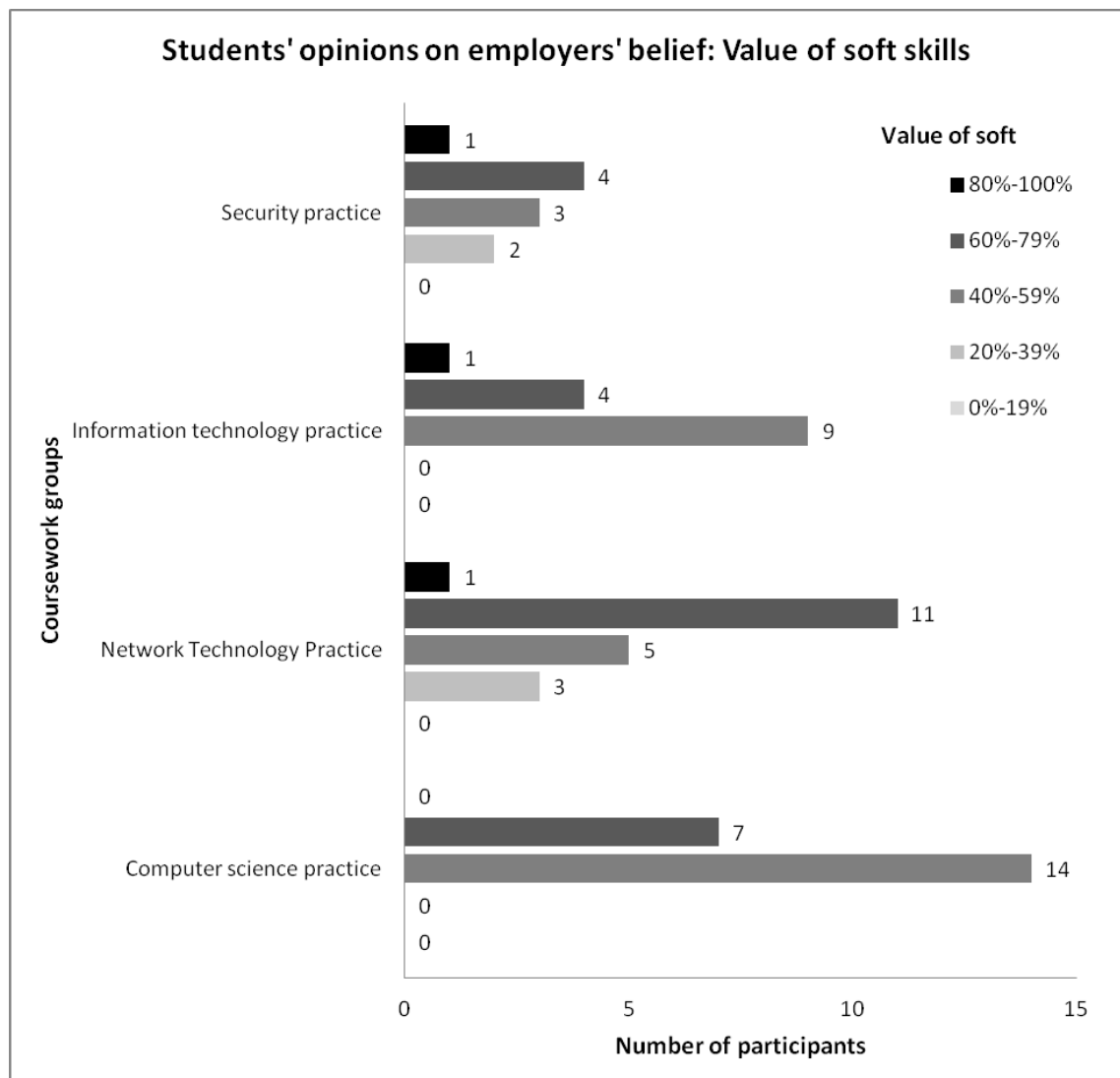


Figure 54. Number of participants who agreed on the value of non-technical skills, showing their opinions of employers' beliefs about non-technical skills in comparison with technical skills, grouped by their courses.

Further analysis considered other factors that could possibly cause students to believe that non-technical skills were of higher value. The ages of the students could be a factor. Figure 55 shows the number of participants agreed on the percentage range of the same question (question 22) that asked about employers' valuations of non-technical skills compared to technical skills, grouped by age. The results showed that the rate of appreciation of non-technical skills increased for the participants aged more than 27. Ten of 18 participants (55%) weighed the value non-technical skills in the range of 60%-79%, and another one participant selected the range of 80%-100%. In total 11 (61%) participants, who were 27 or more years of age, perceived that employers valued the non-technical skills more highly than technical skills.

Meanwhile, in the other age groups (19-22 and 23-26 years of age) the majority of the participants favoured an equivalent value of non-technical and technical skills. Eight (57%) from 14 participants from age group of 19-22 years, and 19 (also 57%) from 33 participants in the age group of 23-26 years, were in this category.

This limited data indicates that the older age of the participants seems to be the factor of increasing the awareness of the value of non-technical skills. However, again a larger group of participants may better support this claim. The author suggests further research with a larger group of participants of varying ages.

Another factor to analyse was the participants' work experiences. Please refer back to Figure 47 and Figure 48 for the distribution of participants' working experience in total and separated into three age groups. The overall weight of non-technical skills compared to technical skills, grouped according to the participants' work experience, is shown in Figure 56. The results showed that the majority of the participants without work experience, in fact, have a higher rate of finding non-technical skills preferable. The majority of 12 (50%) from 24 participants without work experience weighed the value of non-technical skills more than technical skills. However, 22 (54%) from 41 experienced participants weighed non-technical skills equally with technical skills. This limited data could demonstrate the greater awareness of the value of non-technical skills by inexperienced participants.

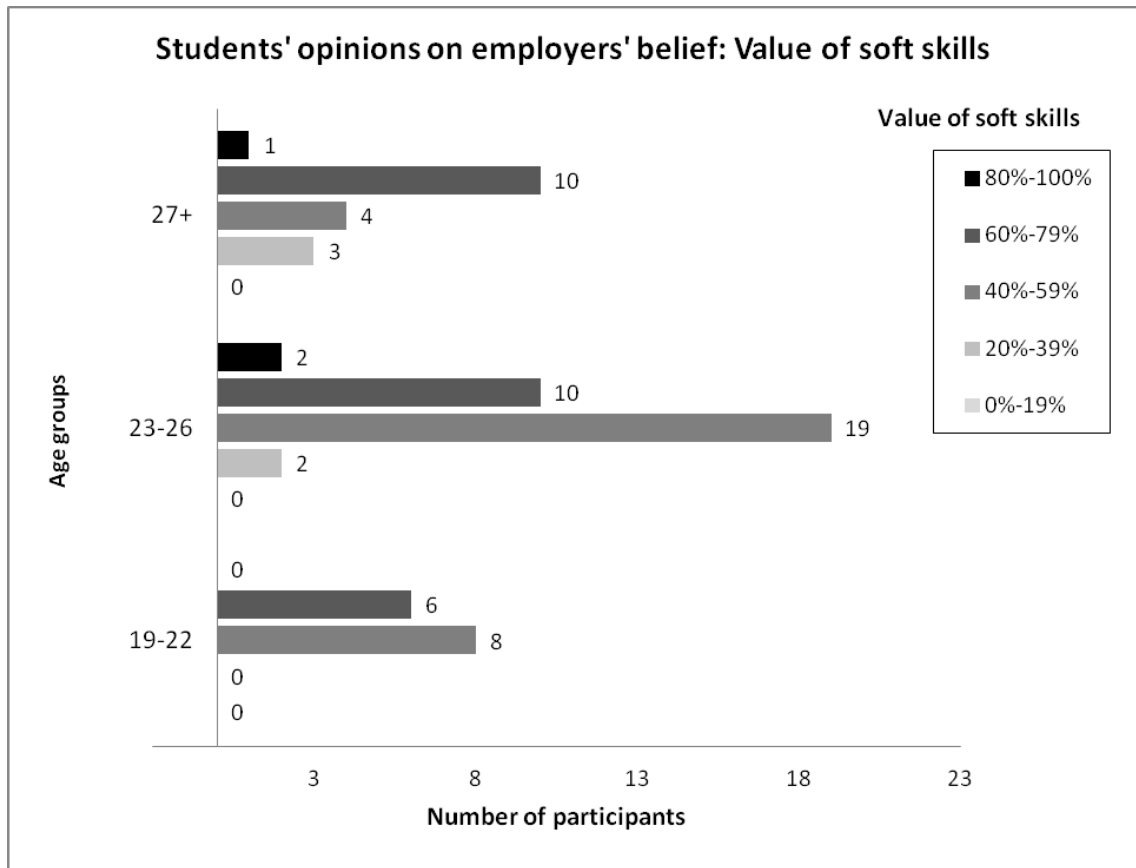


Figure 55. Number of participants agreed on the percentage range of employers' expectations of non-technical skills value compared to technical skills, grouped by age.

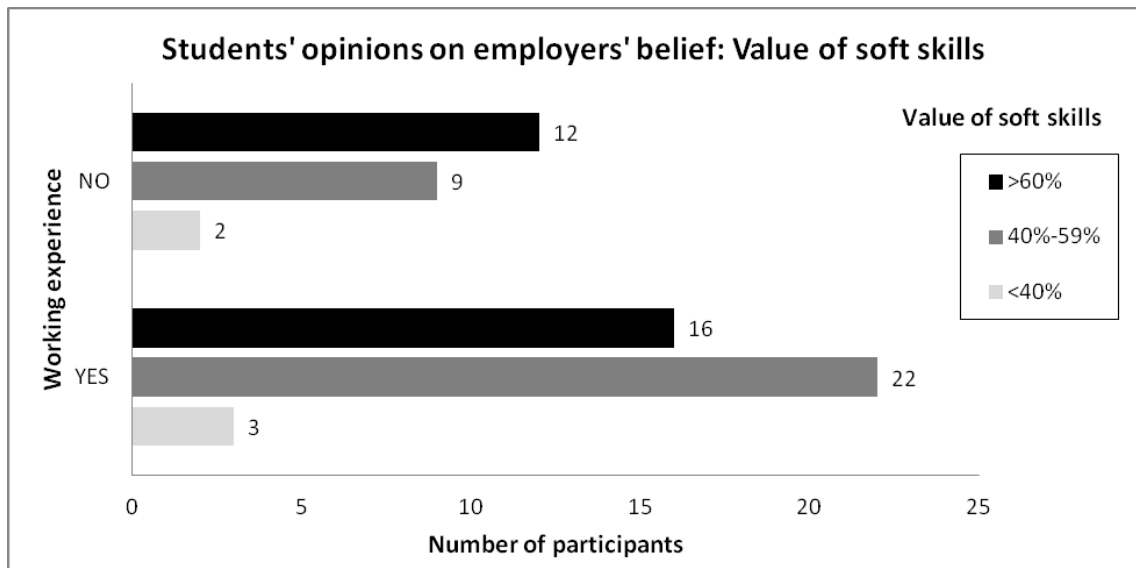


Figure 56. Number of participants agreed on the percentage range of employers' expectations of non-technical skills compared to technical skills, grouped by work experience.

A further analysis, which distinguishes between the effect of work experience and age groups, is presented in this section. Separating the inexperienced group from the other participants showed that age seems to be a stronger factor in students valuing non-technical skills more highly. Figure 57 shows the number of participant agreeing on the value of non-technical skills, comparing participants with and without work experience, and also grouped by age. Focusing on the participants with work experience in the age of 27 or more group, 7 (55%) of 13 participants believed that the employers valued non-technical skills more than technical skills. Meanwhile in the other age group, only 30% of the participants have this belief.

Further focusing on the participants without work experience, participants in both age groups, 19-22 and more than 27 year of age, had a majority of 3 (75%) of 4 participants who believed that employers are looking for non-technical skills more than technical skills in new candidates. Meanwhile, only a minority of 6 (40%) of 15 participants of 23-26 years of age had a similar belief. Although the result that the older age group, of more than 27 years, corresponded to the experienced participants' group, the reason why the younger inexperienced participants also believe that non-technical skills are needed should be investigated further. The results of this analysis were derived from a relatively small population; however, the result might be seen as identifying another possible factor to be investigated further with a larger population.

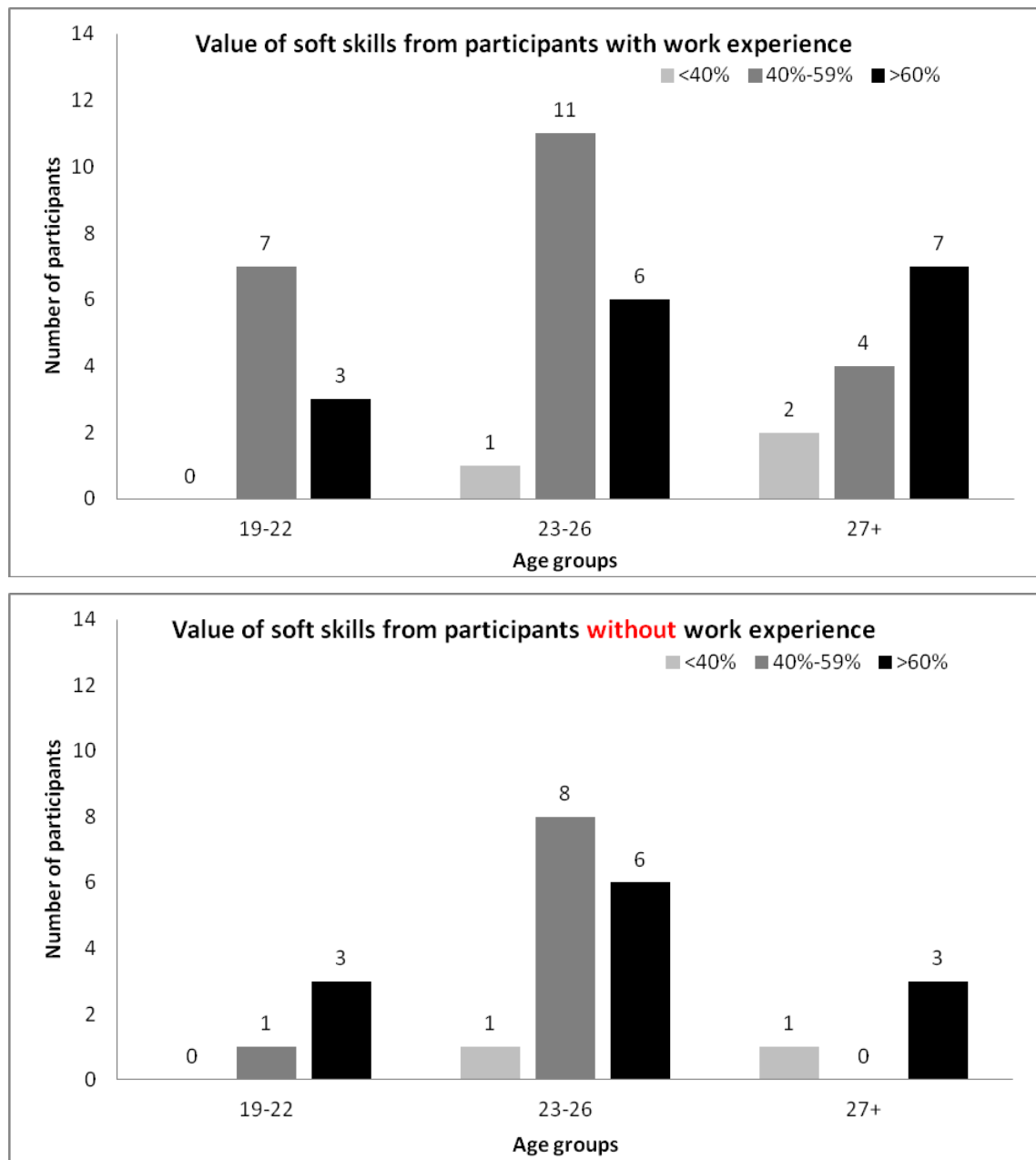


Figure 57. Comparison of the number of participants agreed on the percentage range of employers’ expectation of non-technical skills value between experienced and non-experienced participants, group by age.

Question 16, “*What soft skills do you think an employer will require from you?*”

Question 16 asked the participants about their opinions of those non-technical skills which they believed could be required by an employer. Responses to this question are displayed in Figure 58. Communication skills and team working skills are the top two skills that the participants believed were likely to be required by employers (Makasiranondh, et al., 2011b).

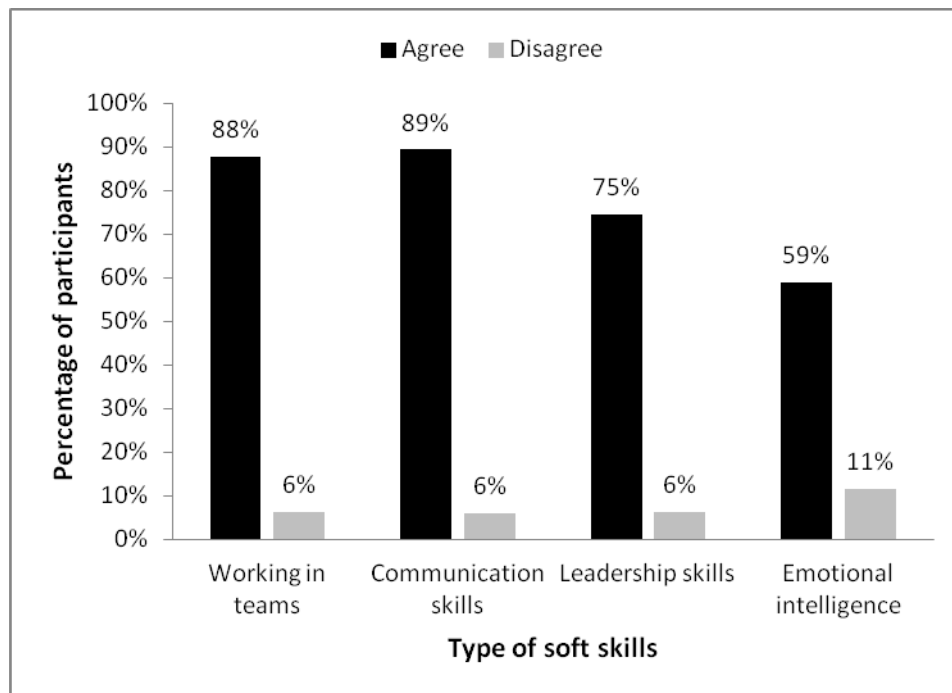


Figure 58. The relative importance of non-technical skills required by employers, as evaluated by participants.

Some further skills were suggested by the respondents; these are presented in the following table:

Table 26: Other skills that employers could require from the participants

	Skills	Number of times mentioned
Non-technical	Troubleshooting skills	1
	Project management	1
	Punctuality	1
	Criticism management	1
	Speed and accuracy	1
Technical	General technical skills	4
	Theoretical knowledge	1
	Programming development	2

These other skills mentioned by the participants revealed an interesting concern voiced by the students, specifically regarding their skills development opportunities. Although the questionnaire was focused on non-technical skills, there were a number of participants who mentioned the value of the technical counterparts. Both groups of skills are essential for graduates.

6.3.3 University and teaching of non-technical skills

Question 17 was “What are the soft skills development opportunities you think the university, especially in internetworking units, should provide for you?”

Question 17 asked whether the internetworking units should also offer students the opportunity of developing non-technical skills. The participants weighed the skills that the university should provide in a very similar manner to that shown in Figure 58. The highest rated skills were communication (84%) and working in teams (82%). Figure 59 displays these two skills as percentages, along with two other important skills, leadership skill and emotional intelligence. These answers imply that students are expecting the university to provide opportunities for the development of these skills in particular ways.

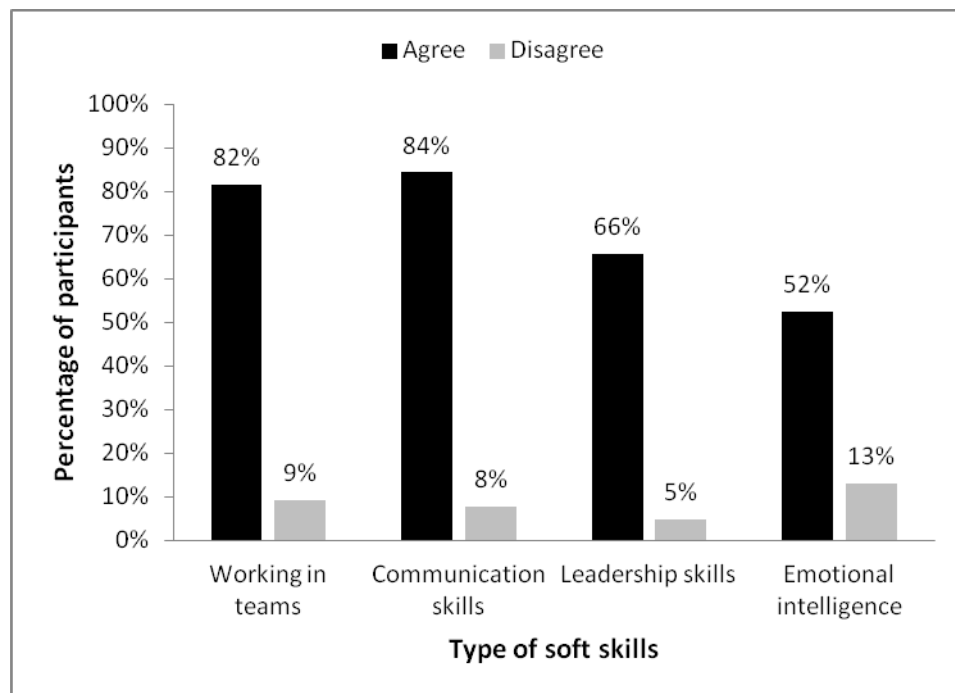


Figure 59. The relative non-technical skills that university should provide in internetworking units, as evaluated by participants.

Question 18, “What do you think will be the best mode of delivery for soft skills units?”

Question 18 asked how non-technical units should be delivered. The participants agreed that it was preferable to learn non-technical skills from near real-life or practical projects (89%). Other methods that also may interest students were the normal classroom (74%) and role-playing activities (60%). In fact, the lowest rate of

appreciation was displayed for the online mode of teaching; both as self study (24%) and via online course (11%). This finding showed the potential usability of project-based units as an enhanced tool for influencing students to learn non-technical skills. However, it also showed the potential challenges to be overcome with on-going online courses (Makasiranondh, et al., 2011b).

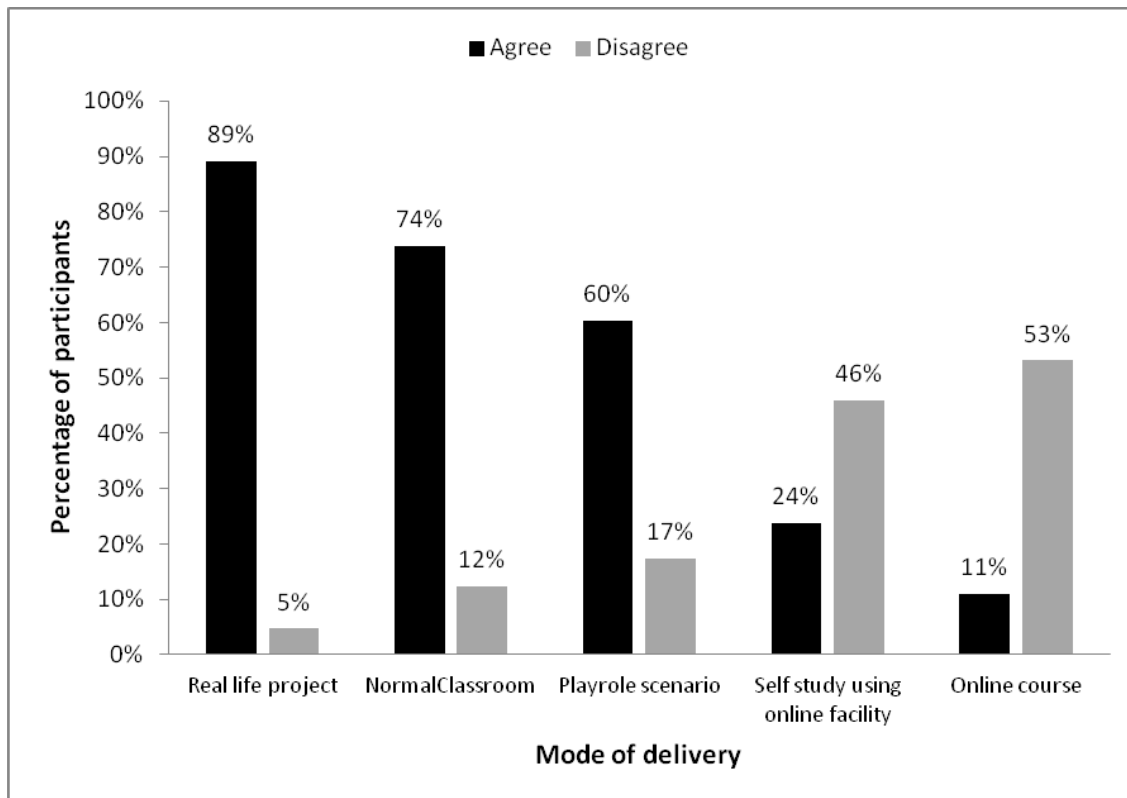


Figure 60. Preference of delivery mode of non-technical skills units

Results from question 18 suggested that it was desirable that non-technical skills should be taught via face-to-face and not in an online mode. For instance some of the comments included the following statements: “*Soft skills are a real life experience*” and “*I would prefer to learn from real life experts.*” A further parameter was studied in Question 19 about how non-technical skill units could be conducted.

Question 19 was “*If you had a chance to create a new internetworking curriculum, how would you like to include some dedicated soft skills units?*”

Question 19 has four statements for the participants to evaluate. These were:

- I prefer to have only ONE unit dedicated to soft skills for the entire study period.

- I prefer a chain of continuous units that run consecutively through out my course.
- I prefer the project units to challenge me into building some soft skills
- I would have learnt soft skills myself and am not interested in learning them from any university units.

Figure 61 shows the percentage agreement of each option in this question. From the results, the participants preferred the non-technical skills to be integrated with project work (72%). This trend again corresponded with Makasiranondh et al.'s finding (2011b), the author of this thesis. However, the difference from the previous report was an increasing appreciation of normal technical units in building non-technical skills, from 56% to 63%.

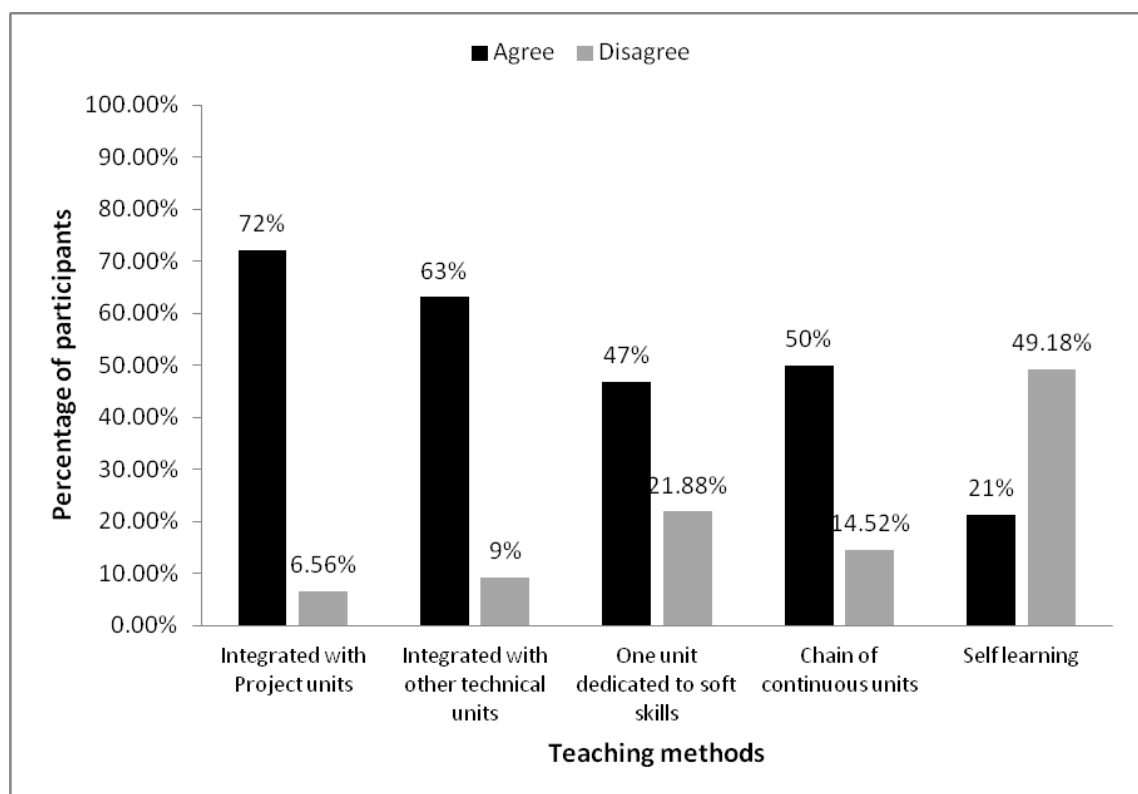


Figure 61. Preference of how non-technical skills can be taught

A further difference was the shift in an appreciation of the approach of distributing non-technical skill units throughout the course. Instead of one dedicated non-technical skill unit in the course, the current data showed more appreciation of having a chain or series

of non-technical skills units enhancing the development process throughout the whole course. This finding could mean that the students prefer to develop such skills over time, rather than having only one chance to learn from a single teaching unit.

In fact, another option that could be drawn from the data was to integrate non-technical skills contents in other normal technical units. Sixty three percent of students agreed on this option. The least agreeable method, which incurred the highest disagreement rate, was the option of non-university self study (21% agreement and 49% disagreement). This finding suggested that students expect to have some chance of non-technical skills development in university and are not interested in studying these topics on their own.

The data from this question suggested an encouragement to have more non-technical skills related activities in normal technical units, which would help the students to build their skills throughout their courses. The chance for students to develop non-technical skills will be spread over time rather than a one-off offering for the entire course. For example, the non-technical skills activities could include random group work or some other activity that forced the students to communicate via an online facility such as the unit's discussion board on Blackboard. Although these particular activities could be seen in a normal teaching unit, the author suggests that it would be useful for the lecturer to state clearly from the beginning of the unit the value of non-technical skills that students could gain from such activities. Students may not realise the importance of these skills and by relying on individual work they may miss the opportunity to develop the skills in a focused way.

6.3.4 *Specific opinions about communication skills*

Question 45, *“Do you think the current networking curriculum helps you to build overall communication skills?”*

Question 45 asked the participants about their opinion of the current networking curriculum's contribution toward building their non-technical skills, specifically communication skills. The question allowed the participants to voice their opinions by selecting from a five point scale. Figure 62 shows the percentage agreement from participants' responses to this question.

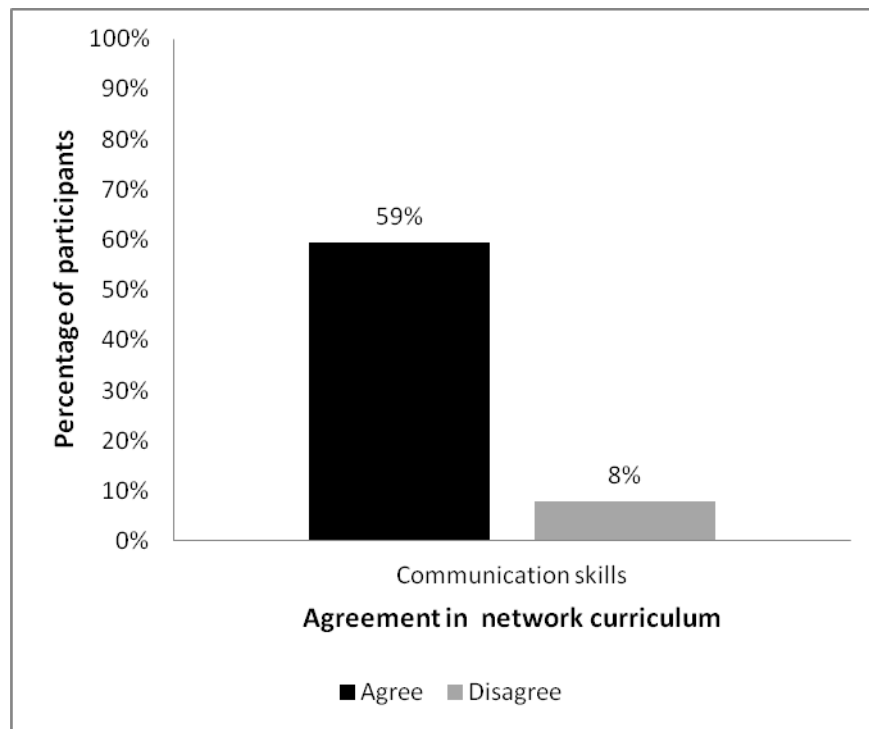


Figure 62. Percentage agreement of the overall participants' opinion specific about communication skills in the current Networking curriculum.

When the percentage of participants' appreciation of communication skills is compared to their appreciation of non-technical skills within their course work (Figure 62 and Figure 49), the trend of the two percentage rates were similar. Fifty nine percent of participants appreciated the value of the networking curriculum in building their communication skills, while a similar percentage (60% of all participants) also appreciated the value of their course work in building their non-technical skills.

Question 46 was *“Do you think the current networking curriculum helps you to build the following specific communication skills?”*

Question 46 was designed to measure the value of specific communication skills in the current internetworking curriculum. In total there were 63 respondents to this question. Figure 63 shows an agreement percentage for each specific communication skill, namely listening, reading, presentation, oral communication and written communication skills.

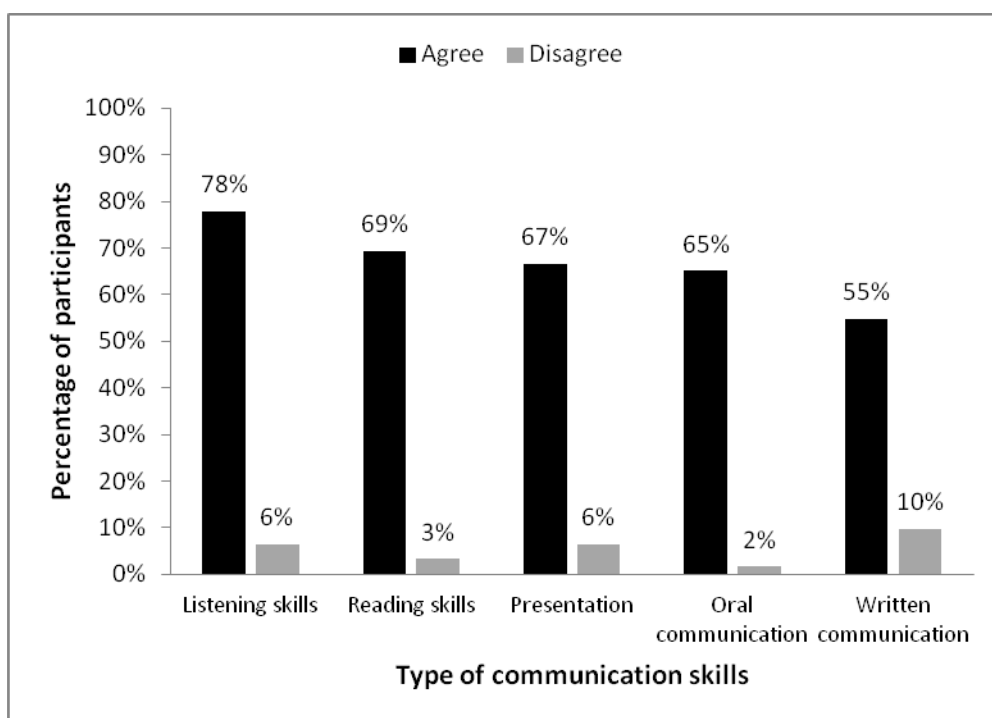


Figure 63. Percentage agreement on the current value of networking curriculum in term of building specific communication skills.

Amongst all the communication skills mentioned, listening skills received the highest agreement percentage. The value of the current networking curriculum for building listening skills was confirmed by 49 participants (78%). Reading skills, presentation and oral communication skills were voted similarly and could be ordered as second, third and fourth most valuable by the number of participants of 43 (69%), 42 (67%) and 41 (65%), respectively. The lowest vote of communication skills in the networking curriculum was writing skills, with only 34 (55%) participants agreeing.

The results indicated a strong emphasis on practice opportunities for listening skills in the current networking curriculum. A strong emphasis on listening and reading skills may be due to normal class activities which include lectures and laboratory workshops. Other skills such as presentation and oral communication also were voted as being of a secondary rank. Students could have opportunities to develop presentation and oral communication skills from normal laboratory sessions which collaboration and discussion of the laboratory results were emphasised. However, the results indicated a lower appreciation to the limitation of the opportunity to practise writing skills in the current curriculum. This could be due to the curriculum which emphasised hands-on practical activities and with less focusing on report-type submissions. Previous literature could not show that the practicing of hands-on skills in laboratories directly emphasized

the development of reading and writing skills (Guthrie & Alao, 1997, p. 99). On the other hand, various examples showed that the writing skills would be build during the student learning to create a laboratory report (Cunningham, 1994; Oakley, Connery, & Allen, 1999; Ruff & Carter, 2009). Glynn and Muth (1994, pp. 1058-1059) pointed the reason that initially hands-on activities using a short-term working memory to process the learning information, whereas reading and writing skills are utilising the longer term memory which involved with the other higher order learning such as generalisation and elaboration. Hence the participants may have felt that the lack of the chance to practice writing skills as they had less report-like assignments.

6.4 An analysis of the participants' self evaluation of their non-technical skills

This section presents a result and analysis of the survey's self evaluation questions about the participants' non-technical skills.

6.4.1 Familiarity

The participants may have different opinions about their familiarity with each non-technical skill. This sub-section presents the results of the survey question that asked the participants about their familiarity with particular non-technical skills.

Question 23 was *"Please identify the soft skills that are familiar (you heard about them before)"*

Question 23 asked the participants to express their opinion on each particular non-technical skill, e.g. communication, team working, leadership and emotional intelligence. The participants were able to specify their familiarity with each skill through a standard Likert scale from strongly disagree to strongly agree. The researcher then grouped the results into three categories of agreement: skills were familiar, neutral or not familiar. The results from this survey question are presented in Figure 64.

The majority of the participants believed they were very familiar with communication skills by the agreement score of 91%, as expected. Team working skills and leadership skills were also perceived as familiar skills by the participants with agreement scores of 89% and 86% respectively. Meanwhile, emotional intelligence skills were perceived as unfamiliar skills, with only 47% agreement that these skills were familiar.

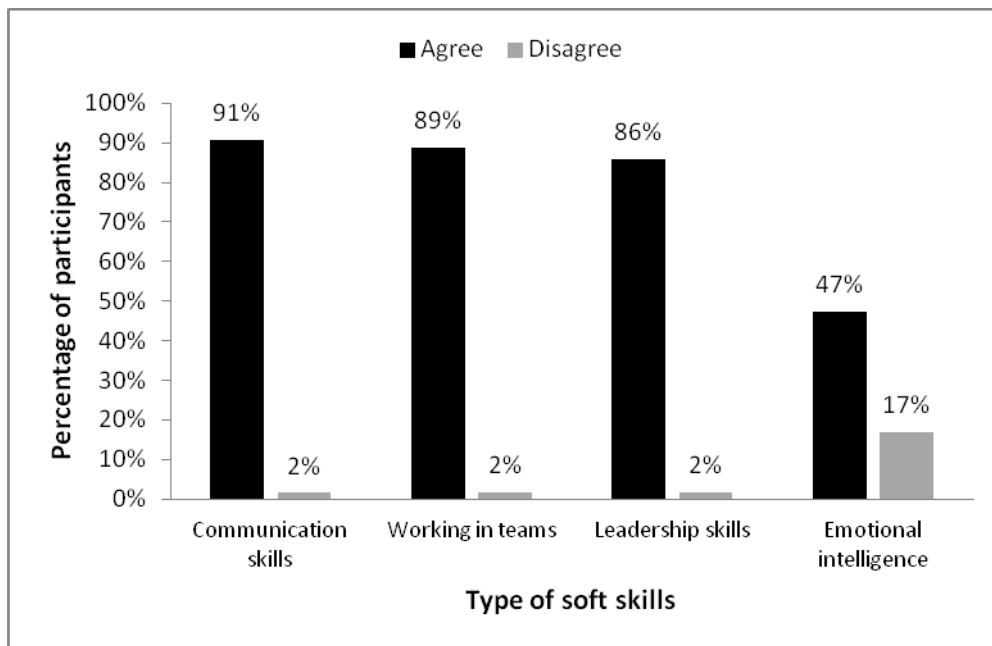


Figure 64. Familiarity of the participants with each particular non-technical skill.

The result of this analysis of the familiarity with skills corresponded with participants' perceptions about the order of importance of each non-technical skill, as shown in Figure 58. It also corresponded with participants' perceptions of the university's teaching of non-technical skills, illustrated in Figure 59. It could indicate that university students may have related the importance of the particular non-technical skills according to their familiarity. In other words, the common non-technical skills, such as communication skills, were perceived as the most important and were emphasised in the university teaching. Moreover, the less familiar skills, such as emotional intelligence, were less emphasised by the university and therefore were perceived as being non-important. This finding could indicate an extra obligation in the university setting to introduce and provide opportunities for students to be exposed to such skills.

6.4.2 Self evaluation results

Questions used in the self evaluation section in the questionnaire were designed to capture the levels of satisfaction with the participants' learning experience for specific non-technical skills, e.g. communication skills, leadership skills, team working skills and professional working skills or emotional intelligence skills. The questions asked the participants to specify their confidence level for each skill in five-point Likert scale. These questions were numbered 24 through to 41 in the questionnaire, and are listed in Table 27 with their category of skills measurement.

Although the self evaluation questions gave subjective responses from the participants' points of view, these questions were used to measure the confidence levels of the participants only and not intended to measure their non-technical skills. Further investigation in this area is recommended by the author in regard to the measurement of non-technical skills in each sub-category, e.g. communication skills, team working, leadership skills and emotional intelligence. The questionnaire could be further used as a pre- and post-testing for detection of perceptual changes of the participants before and after the specific course. However, the research methodology and data collection procedures may need to be redesigned for this further requirement.

Table 27. List of questions in the self evaluation section in the non-technical skills questionnaire

Question	Measurement
24. People in my project team can verbally understand me well.	Communication
25. People in my project team can understand me well when I use non-verbal signals.	Communication
26. I feel confident when communicating with my lecturers.	Communication
27. I feel confident to communicate with clients in the real work environment.	Communication
28. I feel that I can lead other team members to conduct group work.	Leadership
29. I prefer to follow other team members' decisions, regardless of my own opinion.	Team work
30. I listen to every opinion of my team members before making the decision.	Team work
31. I prefer not to work in a team.	*~Team work
32. I feel more confident working alone.	~Team work
33. I feel more comfortable working with other people.	Team work
34. I want to work with other people with different backgrounds.	Team work
35. During project work, I prefer to work only with friends I've known previously.	Team work
36. I am prepared to take responsibility for any group decision that my team members make, even if it is in conflict with my own opinion.	Team work
37. I feel I can persuade people in my team to believe in my decisions.	Team work
38. I don't want to express my own opinions when it comes to group decisions.	~Team work
39. I don't think a professional approach is necessary as we are still students.	Professional
40. I have always compared my work to the professional standards.	Professional
41. I feel that other people in my team cannot understand me well enough.	Comm/Team

*Note: ~ indicates a reverse measurement

6.4.2.1 The overall all self evaluation results

The overall result from each question is presented in Table 28.

6.4.2.2 Evaluation results related to communication skills

Questions numbered 24 to 27 represented a set of variables encoded for the measurement of communication skills. Question 24 *“People in my project team can verbally understand me well”* tried to measure participants’ self satisfaction with their communication skills during project units. There were 57 (87%) of 65 participants who agreed on their communication capability during the project work. Similar to question 24, question 25 *“People in my project team can understand me well when I use non-verbal signals”* focused on non-verbal communication during the project work. Only 41 (64%) participants appreciated their own non-verbal communication ability.

Question 26 *“I feel confident when communicating with my lecturers”* was trying to measure the participants’ communication skills from a different angle, from that of ordinary classroom-based communication with lecturers. Forty seven (73%) participants identified that they feel confident to communicate with lecturers. On the other hand, question 27 *“I feel confident to communicate with clients in the real work environment”* was attempting to measure the participants’ confidence in real working environments. Forty six (72%) participants evaluated themselves as confident with basic communication skill in the work environment.

According to Table 28, the highest agreement percentage amongst the communication variables was with question 24, measurement of communication activity within the participants’ project work. This small result could indicate that the project-based work seems to encourage students to practice their communication skills. On the other hand, the lowest measurement was of the usage of non-verbal communication. This finding could indicate a lack of opportunity to practice using non-verbal communication.

Table 28. Overall result from question 24 through question 41 in number of response and percentage.

Question	Number of response						
	SD*	D*	N*	A*	SA*	#	Mean
24. People in my project team can verbally understand me well.	1	1	6	38	19	65	4.12
	2%	2%	9%	58%	29%		
25. People in my project team can understand me well when I use non-verbal signals.	0	3	20	29	12	64	3.78
	0%	5%	31%	45%	19%		
26. I feel confident when communicating with my lecturers.	1	3	13	32	15	64	3.89
	2%	5%	20%	50%	23%		
27. I feel confident to communicate with clients in the real work environment.	1	5	12	33	13	64	3.81
	2%	8%	19%	52%	20%		
28. I feel that I can lead other team members to conduct group work.	0	3	21	28	13	65	3.78
	0%	5%	32%	43%	20%		
29. I prefer to follow other team members' decisions, regardless of my own opinion.	5	19	21	19	1	65	2.88
	8%	29%	32%	29%	2%		
30. I listen to every opinion of my team members before making the decision.	2	0	9	32	20	63	4.08
	3%	0%	14%	51%	32%		
31. I prefer not to work in a team.	8	26	17	12	1	64	2.56
	13%	41%	27%	19%	2%		
32. I feel more confident working alone.	2	15	23	20	4	64	3.14
	3%	23%	36%	31%	6%		
33. I feel more comfortable working with other people.	1	6	24	24	10	65	3.55
	2%	9%	37%	37%	15%		
34. I want to work with other people with different backgrounds.	2	5	16	32	10	65	3.66
	3%	8%	25%	49%	15%		
35. During project work, I prefer to work only with friends I've known previously.	4	13	25	17	5	64	3.09
	6%	20%	39%	27%	8%		
36. I am prepared to take responsibility for any group decision that my team members make, even if it is in conflict with my own opinion.	4	6	14	35	6	65	3.51
	6%	9%	22%	54%	9%		
37. I feel I can persuade people in my team to believe in my decisions.	1	5	24	31	3	64	3.47
	2%	8%	38%	48%	5%		
38. I don't want to express my own opinions when it comes to group decisions.	10	30	15	10	0	65	2.38
	15%	46%	23%	15%	0%		
39. I don't think a professional approach is necessary as we are still students.	16	29	11	8	1	65	2.22
	25%	45%	17%	12%	2%		
40. I have always compared my work to the professional standards.	1	6	19	36	3	65	3.52
	2%	9%	29%	55%	5%		
41. I feel that other people in my team cannot understand me well enough.	12	31	16	6	0	65	2.25
	18%	48%	25%	9%	0%		
*Note SD=Strongly Disagree, D=Disagree, N=Neither agree nor disagree, A=Agree, SA=Strongly Agree.							

6.4.2.3 Evaluation of results related to leadership skills

Questions numbered 28 to 30 represented a set of variables encoded for the measurement of satisfaction with leadership skills. Question 28 *“I feel that I can lead other team members to conduct group work”* measured participants’ self satisfaction with leadership skills learnt during their project work. Table 28 shows 41 (63%) of 65 participants agreed on their capacity for leadership. Although this study involved only a limited number of participants, the percentage agreement was low when compared with other measurements (e.g. 88% agreement percentage of communication skills in question 24). This lower agreement percentage could indicate the limited opportunities for practicing leadership skills during course work.

Interestingly, the previous analysis in section 6.3.2 and section 6.3.3 indicated the students’ expectations for developing leadership skills, so that leadership skills scored only third place after communication and team working. However, self evaluation results from question 28 showed a lower confidence in applying leadership skills. This finding may indicate it is necessary to reconsider the emphasis on leadership skills-building activities in university courses.

Answers to Question 29 *“I prefer to follow other team members’ decision, regardless of my own opinion”* were not conclusive. The results in Table 28 show that the three possible answers, disagree, neutral to strongly agree, were selected by groups of very similar sizes. Twenty four (37%), 21 (32%) and 20 (31%) participants disagreed, were neutral and agreed, respectively. Therefore the results from this question are omitted from this analysis.

Question 30 *“I listen to every opinion of my team members before making the decision”* pointed out the need for communication skills within leadership skills. The majority of 52 (83%) participants agreed with this statement. This finding reveals the necessity for good communication skills as part of overall leadership skills. Although the confidence rate of participants’ leadership capabilities is lower than their confidence in communication skills, the necessary component of good communication with the team member with the leadership role was evident.

6.4.2.4 Evaluation of results related to team working skills

Questions numbered 31 to 38 and 41 were designed to capture the participants' opinions about their team working skills, from various perspectives. The overall response to these questions was also presented in Table 28.

Questions 31 to 33 measured participants' willingness to work in groups. Question 31 and 32 "*I prefer not to work in a team*" and "*I feel more confident working alone*" were negatively worded to test participants' preferences about working in groups. Meanwhile, question 33 "*I feel more comfortable working with other people*" was a positively worded version of the combination of questions 31 and 32. The majority of the participants preferred to work in groups. While 34 (53%) of 64 participants disagreed with the statement in Question 31, the majority of the participants, 34(52%) from 65, agreed with the statement in Question 33 that they felt more comfortable when working with other people.

However, when the participants were asked Question 32 about their confidence when working alone, there was not a clear majority. The responses to question 32 were that 17 (27%), 23 (36%) and 24 (38%) disagreed, were neutral and agreed, respectively. This could be due to the question needing to be more clearly worded. It is also possible that some of the participants felt confident in their ability to handle the work themselves but also preferred to work in a group. However, with only limited results, these conclusions could not be drawn.

Further investigation of the participants' preferences for specific types of members within a working group was carried out by the following questions. Question number 34 "*I want to work with other people with different backgrounds*" was a positive measurement of a preference for a mixture of team members, whilst question number 35 "*During project work, I prefer to work only with friends I've known previously*" was the negative measurement. The response to question 34 showed the majority of the participants, 42 (65%) from 65, prefer to have a mixture of team members. This result showed a positive perspective, that of participants preferring a mixture of team members and benefiting from a wider range of possible opinions in team discussions. However, the responses to question 35 did not distinguish between participants who agreed or disagreed about having only well-established friends in a work team. Responses to question 35 were that 17 (26%) participants disagreed about having only

friends as a team members, 22 (34%) participants agreed and the majority 25 (39%) held a neutral opinion. The author recommends re-defining question number 35 and testing a larger sample of participants.

Another component of good team working skills is that offered by the 'team player' (Linehan, Lawson, & Doughty, 2009). In an ideal situation, for example, every team member assumes the same level of responsibility for the team's decisions. Question 36 "*I'm prepared to take responsibility for any group decision that my team members make, even if it is in conflict with my own*" asked the participants about their awareness of such a situation. The majority of the participants 41 (63%) from 65 respondent agreed with this statement. Therefore, although the results are limited, responses indicated that many of the participants identify themselves as having good team working skills.

Persuasion is a necessary team working skill, which promotes critical thinking and effective team decisions (Knights & McCabe, 2000, p. 1493; Roman, 2010) . A mixture of persuasive team members can draw advantages and disadvantages to the team's attention, potentially making the decision clearer, effective and more precise. The result from question 37, which asked "*I feel I can persuade people in my team to believe in my decisions*", had a majority of only 34 (53%) from 64 participants agreeing about their confidence in their persuasive ability. Although there was a limited number of participants in this study, this finding of lower confidence in persuasive skills may indicate another reason for the university to design the curriculum to address the issue accordingly.

Team work skills could also be reflected by the activeness of the members in the team. Question 38 was negatively worded as "*I don't want to express my own opinions when it comes to group decisions*". This question tried to measure the participants' opinion about being an active team member. Forty (62%), the majority of the participants, disagreed on this statement. This finding showed that the majority of networking students identified themselves as capable of being an active member in the group.

Finally, communication ability within a team working environment is also important. Question 41 was negatively worded as "*I feel that other people in my team cannot understand me well enough*" to confirm the participants' opinion, in a similar manner to that used in Question 24. The majority 43 (66%) participants disagreed with this statement, showing the participants' beliefs in their team communication skills.

6.4.2.5 Evaluation of results related to other professional skills

Question 39 and 40 were designed to capture participants' opinions on other professional skills. Question 39 was negatively worded as "*I don't think a professional approach is necessary as we are still students*", which allowed the participants to express their opinion on professional skills as students. Forty five (69%) participants, the majority, disagreed with this statement. This finding showed that the majority of networking students valued professional working standards even though they were students.

Consequently, Question 40 was positively worded as "*I have always compared my work to the professional standards*". Thirty nine (60%) participants, the majority, agreed with this statement. This information may be interpreted as meaning that the student participants are also concerned about the quality of their work and also keen on comparing their work with other professional standards.

6.5 Analysis of the sources of non-technical skills development

A learning source for non-technical skills is also vital for the students and IT curriculum designing process. Discovering the participants' opinions about the source of their non-technical skills development may have potential benefits for their educators.

Question 42 asked the participants to rate the sources from which they believed they had learnt their non-technical skills. Figure 65 shows the percentage agreement with various sources of learning non-technical skills, from students' perspective. The topmost sources were social activities and work experience, agreed upon by 81% of the participants.

On the other hand, normal university teaching activities were found by the majority of the participants to contribute less to the development of their non-technical skills. They received only a 44% agreement score.

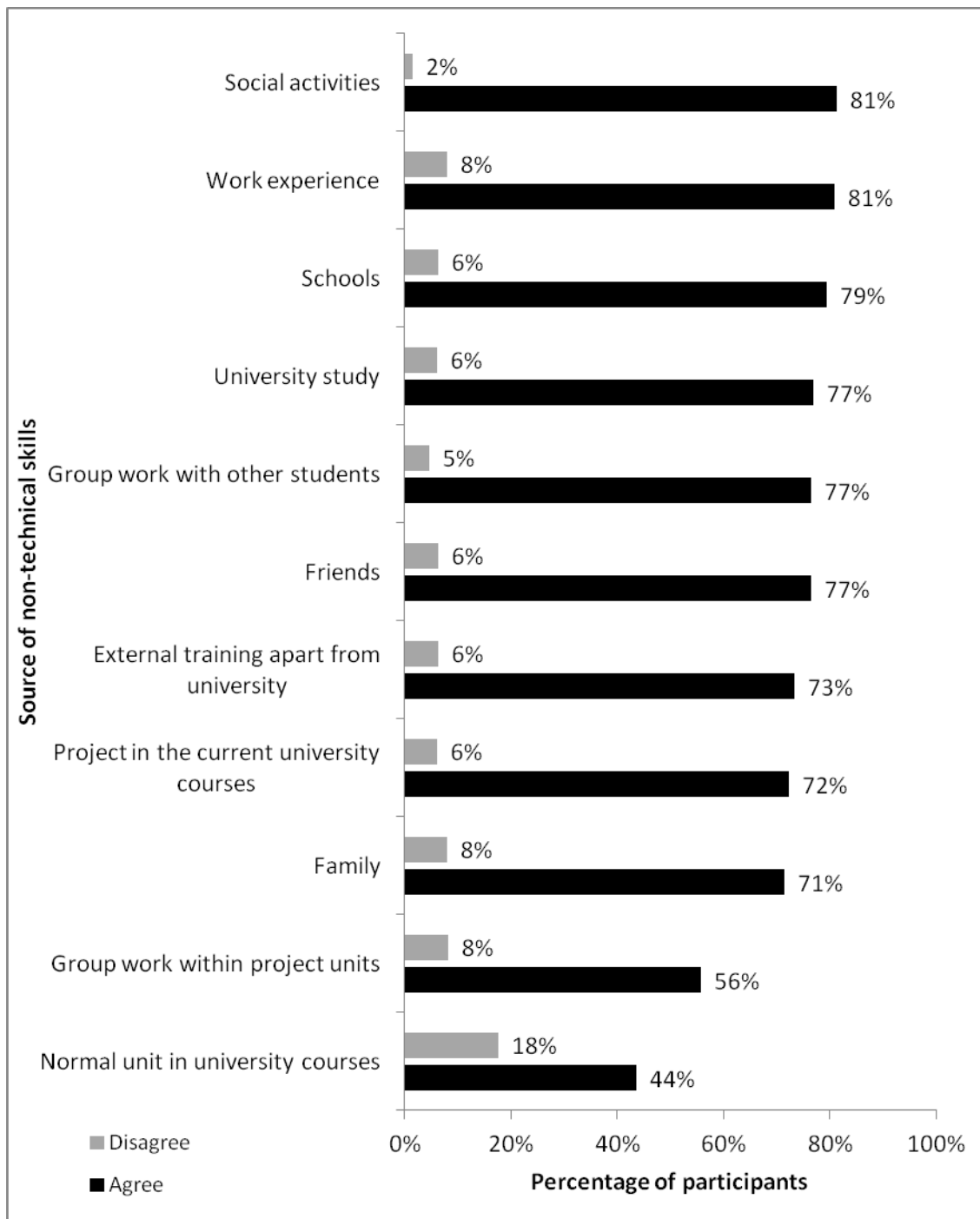


Figure 65. Percentage agreement on various sources of non-technical skills.

Meanwhile, 72% of the participants voted the project units studied in their university courses as a source of their non-technical skills; only 56% of the participants believed that group work within the project unit was a valuable source, compared with completing the project unit itself. It is possible that this finding could indicate that students would have preferred to work on individual projects, but no data was collected to substantiate this idea.

Another interesting point was that the participants also voted the training courses run by external providers as a strong contributor to their non-technical skills learning. Seventy seven percent of the participants agreed on the value of this source of training. This finding may indicate an opportunity to introduce corporate-styled training into university-based IT courses.

6.5.1 Comparison of the university teaching of non-technical skills with the participants' previous experience.

As the researcher focused on specific non-technical skills and separated the internal university learning source from the participants' experiences, the survey results from questions 43 and 44 are presented in Figure 66 and Figure 67.

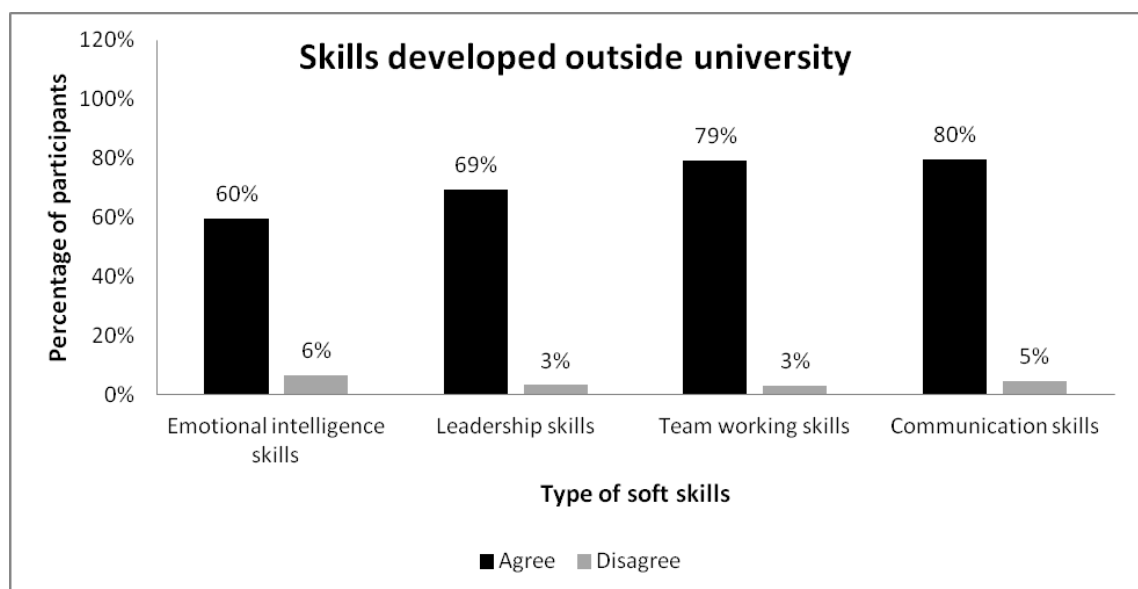


Figure 66. Percentage agreement about the specific non-technical skills that participants believed that they have learnt from their previous experience outside the university.

On one hand, Figure 66 shows that amongst all four skills, e.g. communication, team working, leadership and emotional intelligence, the communication skills received the highest agreement rate (80%) about the skills that the participants learned from previous experience. Team working skills also had a similar score (79%). On the other hand, leadership received only 69% and emotional intelligence received only a 60% agreement score.

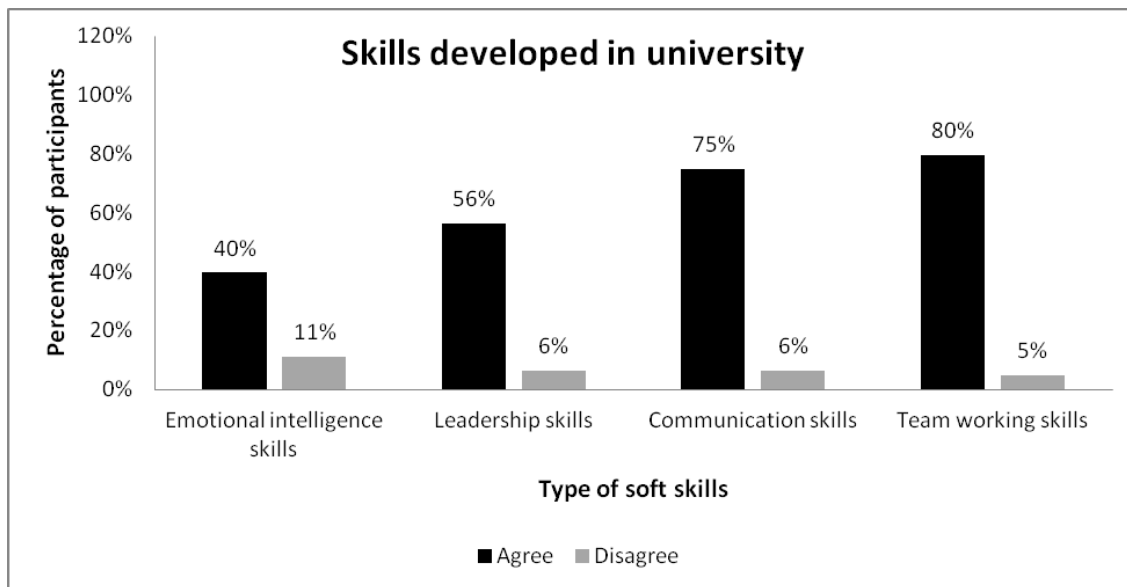


Figure 67. Percentage agreement about the specific non-technical skills that participants believed that they have learnt from the university.

Figure 67 shows the same four skills evaluated by the participants according to their belief that they learnt them from their current university courses. Interestingly, participants believed universities were less important learning sources when compared to external experiences. The agreement percentages of three of the four skills dropped when the universities were evaluated as learning sources. These three skills were communication skills, leadership skills and emotional intelligence skills. Even learning communication skills from universities received only a 75% agreement, less than external experiences as a learning source. Similarly, leadership skills and emotional intelligence skills received only 56% and 40% agreements respectively. In both cases, the agreement percentages for universities as a learning source were less than those for external experiences.

6.6 Summary

This study was based on participants from four course categories, three age groups and the majority had a work experience background. Although data was collected from a small number of participants, the results could indicate a number of potential issues for internetworking education. Further study is recommended by the researcher.

Survey results indicate that the majority of participants believed that their current coursework helped them to build non-technical skills; however, the participants from different courses had varied views on the ways their courses contributed to the

development of these skills. Also, less than half of the participants felt satisfied about the rate at which their coursework contributed to their non-technical skills.

Only a minor percentage of participants believed that non-technical skills were more important, from the employers' perspective, when compared with technical knowledge. Extra curricular activities with an involvement of external industry parties may be recommended for the students and the school to implement. There was evidence that introducing external speakers from industry could raise the awareness of non-technical skills on the part of the students.

Age could be a factor which caused the participants to have a greater awareness of the importance of non-technical skills. On the other hand, work experience seems to have had less effect on this awareness. The small amount of data from the survey indicated that older students may have a stronger perception of non-technical skills than younger, but experienced, students.

In term of the types of non-technical skills, the majority of participants believed that communication and team working skills were the top two skills that employers are seeking from a potential employee. They are also the top two soft skills that participants expect to derive from a university's networking courses. Meanwhile leadership and emotional intelligence skills were less likely to be a matter of concern on the part of the participants. Moreover, students seemed to be less familiar with emotional intelligence skills.

Amongst all the communication skills, listening skills were those that the students thought the network curriculum best provided. Meanwhile, written communication skills were believed to be the weakest contribution. This weak contribution of written communication skills may have been due to the lack of report-type assessment as the curriculum itself was designed to emphasise practical hands-on abilities. Other communication skills such as reading, presentation and oral communication were considered as only moderate contributions.

Students were also expecting that more detail about non-technical skills would be taught in project units. However, students also considered the integration of non-technical skills teaching with a normal classroom setting of technical content as a possible option. The small survey results from this study suggested that offering a series of non-technical skills units would be more favoured than a single unit. Above all, learning

non-technical skills through online and self study modes were considered as the least favoured options.

Students saw university-based study as the secondary learning source of non-technical skills when compared to the primary sources of work experience and normal social activities. Within the university's education system, group assignments and project units were considered as the main contributors; meanwhile regular units were considered as less significant learning sources. Communication and team working skills were two non-technical skills that have a comparatively similar contribution from university study and participants' own experiences. However, students believed that other important skills, such as leadership and emotional intelligence, seemed to be specifically excluded from the curriculum in the university setting.

CHAPTER 7 CONCLUSION AND FURTHER WORK

7.1 Conclusion

The first major focus of this study was to confirm the usability of a remote laboratory in internetworking education. Although the research mainly relied on qualitative data and the findings were not able to be generalised, some conclusion may be drawn.

In internetworking education, in which the learning process is heavily reliant on students' practical usage of laboratories, the provision of local equipment may be both limited and not cost effective for the universities concerned, especially in developing countries and also in remote areas. An alternative, such as simulation software, could be of benefit for use by students when the physical equipment is unavailable or insufficient. However, simulation tools have a number of pedagogical issues due to their unrealistic setting (Makasiranondh, et al., 2010c). The use of a remote access laboratory could compensate these drawbacks of simulation tools, particularly the need for a steep learning curve and the unreality of the setting (Corter, et al., 2007; Ma & Nickerson, 2006). This study could confirm the benefit of using remote laboratory (finding 5.3.4).

The superiority of the traditional physical internetworking laboratory cannot be overlooked (Figure 36). Essentially, students preferred to learn by interacting with the actual equipment in physical laboratories (finding 5.3.1). However, due to the limited availability of such laboratories, this was sometimes not possible. The research findings (5.3.2) concluded that the remote access laboratory should be integrated with internetworking education as a supplementary system, which helped students to learn at their own pace or as an additional component of a classroom-based internetworking laboratory.

The use of a remote laboratory as a set of self practice tools was found to be acceptable by the students in this research. However, an intensive introduction of students to an unfamiliar online learning mode and tools may need to be provided, especially to the students who have not experienced studying in an online mode. Benefits to the students were not only limited to their increasing capability of learning in an online mode, but also exposed them to a realistic learning environment that may be closer to their future work. The responses of a remote laboratory surpass the unrealistic responses of simulation tools, which are usually provided as a replacement of physical laboratories.

A traditional remote access laboratory provided only text-based command line interface (CLI) to remote devices. However, the remote access laboratory demonstrated in this research enhanced the students' learning experience by providing multimedia access (finding 5.4.2), such as real-time video stream of actual devices, pedagogical tool state model diagrams (SMDs) and voice-video communication with instructors (Makasiranondh, et al., 2010c), with the further option of other graphical user interface (GUI) configuration tools (Makasiranondh, et al., 2010a).

The CLI was essential in the remote access laboratory as the main network manipulation tool, although it had some issues when being used as a learning tool. However, the ability to see the actual equipment was voted as learners' top preference, and was considered to be closer to concrete learning. A remote access laboratory benefits from displaying real-time equipment as it helps students relate their internal logical abstractions to concrete physical visuals.

Furthermore, the usual benefit of simulation tools over a physical laboratory was their ability to visualise the logical connection of laboratory equipment. This visualisation of logical connectivity was used as a guide to how a logical model was constructed in student minds. Traditional face-to-face and text-based remote access laboratories lacked this visualisation assistance. SMDs were seen as a benefit through their usage in the traditional classroom (Maj & Veal, 2007; Nuangjamnong, 2009). This research demonstrated that the remote access laboratory can also benefit from the provision of SMDs as a visualised learning resource.

This research demonstrated that SMDs can be integrated within the remote access laboratory distance learning tool, through a simple low-cost web-based communication (Makasiranondh, et al., 2011a). However, the slow response of the preliminary system used in this research was the main obstacle. The current limitation was that SMDs need local connectivity; hence it limited the means to provide software accessibility. Further improvement to overcome this obstacle and further research are needed.

Success in using a remote access laboratory in distance internetworking education would need to be based on a faster connection to equipment than was available in this study, SMD diagrams-software and even better communication with remote instructors. internetworking students, who are new to online learning resources, were heavily reliant on local instructors. The implementation and application of a self-driven facility, such as a remote access laboratory, needed to be adjusted to suit the learning style of

students. Thai students, with a group learning style, may benefit from the provision of a local instructor or a remote instructor who is efficiently accessible in real-time.

In term of soft skills or non-technical skills, internetworking students felt confident of gaining their experience and enhancing their usage of skills through the use of a laboratory, and other team-based technical activities (finding 6.3.3). This study concluded that the emphasis on communication and team working skills in internetworking was important and encouraging a strong belief that soft skills should be delivered by being integrated in both technical and project-based units. However, this study is also strongly concerned that learning such skills in an online-virtual facility would have been problematic (Makasiranondh, et al., 2011b), as students related soft skills to real life experience and would prefer to learn from experts directly. Further investigation on the other supported reasons is needed.

The application of a remote access laboratory to a facilitated online learning resource to distance internetworking students may assist their development of technical skills. However, designing the appropriate activities of using online learning resources in order to encourage internetworking students to develop their soft skills was considered as a challenge. Further work is needed in order to address this problem.

7.2 Limitations

Overall, the limitations of this study were as the following:

- Limitation of resource availability
 - The equipment resources provided to distance students in this study was from Edith Cowan University's shared laboratories, which are normally fully occupied by local students. The implementation and provision of time for remote access to this laboratory was therefore limited.
 - As ECU's students frequently utilised the laboratory, there was a conflict between the availability of ECU's laboratory and the remote participants' available time.
 - With security concerns there were only limited networking protocols that were permitted to be connected through ECU's firewall.
- The limitations of data collection processes

- The recruitment process required the researcher to visit the remote university within Thailand, which added to the cost of research.
 - Participants' selection process was restricted as the participants needed to be currently enrolled in internetworking course and familiar with the operation of internetworking equipment.
 - The two hours work-shop time was considered to be a long session for the participants; however, they still requested more practical usage time. A longer term study could have been conducted if the course providers had officially used the remote access laboratory as their teaching tool.
 - Data transforming techniques such as NVivo, which was normally used to transform qualitative to quantitative, can be applied efficiently to mixed methods if the sample size is large enough (Driscoll, et al., 2007, p.25). This study was concerned with a confined sample size and the author decided to use non-transformative techniques.
 - This study was conducted mainly using a qualitative approach, involving a small number of participants; hence the ability to generalise the conclusion was limited.
 - There was a complication of the data collection process due to the long distance between Thailand and Australia. This caused the data collection to be limited to an online approach to gather data from the small group of eligible participants.
- Limitation of remote access laboratory
 - Bandwidth between the local and remote study sites was the main limitation; providing both a graphical interface, and real-time video at the same time required a larger bandwidth which slowed down the response of the remote laboratory. The higher bandwidth of the National Broadband Network (NBN) (DBCDE, 2010) may increase the future opportunity to use remote access laboratories within Australia; however, on an international basis the final throughput also depends on the condition of the network on the receiving end, especially in a developing country with slower bandwidth.

- SMDs software were designed to be operated locally and needed to have an immediate connectivity to network equipment on the laboratory, which limited the ability to provide the software to remote users. This study could provide the software to remote users, but there was a trade-off with corresponding high bandwidth consumption.
- Limitations of SMD GUI software
 - SMD GUI software is still a developmental phase. Although the current version can identify the connection of network equipment through non-proprietary protocol, SMDs still have a limitation when using with more complex network topology.
 - The current version of SMD GUI can only be used to retrieve network equipment information. The limitation is that the users cannot use the SMD software modifying the equipment configuration directly.

7.3 Further work

In order to study the application of a remote access laboratory in internetworking education, longer term research will need to be implemented. This will include the collection of measurable quantitative variables such as study results. Further research needs to be conducted as a full-semester study, which requires dedicated resources. A larger number of participants and a greater number of groups also need to be studied.

Although SMD software cannot simulate network equipment behaviour, SMD software can be used to integrate to simulation and emulation tools, and displaying simulated network information to the designed SMD diagrams. Although the author has tested such a preliminary integration, he decided to conduct the experiment due to the current software limitations.

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Appendix A. Summary of publications

A.1 Introduction

Along the completion of this thesis, the following articles have been published. There were all seven publications in total. The author would like to conclude these publications in this section. These publications are considered as part of the work consisting in this thesis.

All these publications are supported and relevant to the contents and claims in this thesis. Although, the publications were published while this thesis had been constructed, they do not form part of this thesis. The final draft of working papers could be found at [Appendix F]. Please note that these attached papers are not presented in their published format, due to the conversion. For a precise reference, please refer to the published version.

A.2 Publications list

1. Title	Student opinions on their development of non-technical skills in IT education
Author(s)	W. Makasiranondh, S. P. Maj, D. Veal
Journal	Modern Applied Science
ERA rank	A
Publication date	26 January, 2011
Full paper	Appendix F.1
Available at	http://www.ccsenet.org/journal/index.php/mas/article/view/8856

The conclusions of this paper contributed to the third research question of this thesis; which was about students' opinions of their development of soft skills in internetworking education. The paper confirmed the importance of team-based project units to the students' development of soft skills. It also raised concerns about teaching such skills in an online mode.

2. Title	A pedagogical rich interactive on-line learning platform for Network Technology students in Thailand
Author(s)	W. Makasiranondh, S. P. Maj, D. Veal
Conference	The Thirteenth Australasian Computing Education Conference (ACE 2011)
Conference Location	Curtin University, Western Australia
ERA rank	B
Conference date	17-20 January, 2011
Full paper	Appendix F.2
Available at	http://crpit.com/Vol114.html

This paper contributed mainly to the first two research questions of this thesis, which were about remote access learning environments and the usage of SMDs in internetworking education. It investigated the results of introducing a remote access learning environment to internetworking students in Thailand.

3. Title	An Integrated Multimedia Based Platform for Teaching Network Security
Author(s)	W. Makasiranondh, S. P. Maj, D. Veal
Journal	International Journal of Computer Science and Network Security
ERA rank	C
Publication date	30 December, 2010
Full paper	Appendix F.3
Available at	http://search.ijcsns.org/07_book/2010_12.htm

This paper introduced the provision of a GUI-based device configuration tool in network security class. It demonstrated another possibility of remote access laboratory to provide multiple learning environments for internetworking students.

4. Title	Pedagogical evaluation of simulation tools usage in Network Technology Education
Author(s)	W. Makasiranondh, S. P. Maj, D. Veal
Journal	World Transactions on Engineering and Technology Education
ERA rank	C
Publication date	30 September, 2010
Full paper	Appendix F.4
Available at	http://www.wiete.com.au/journals/WTE&TE/Pages/TOC_V8N3.html

This paper investigated simulation tools that were used in internetworking education. These main simulated-teaching tools were Cisco Packet Tracer and GNS3. This paper contributed as a study of simulation tools in order that they could be compared with the remote access laboratory used in this research.

5. Title	Remote teaching environment for internetworking students in Thailand
Author(s)	W. Makasiranondh, S. P. Maj, D. Veal
Conference	First WIETE Annual Conference on Engineering and Technology Education
Conference Location	Seri Hotel, Pattaya, Thailand
Conference date	20 - 25 February, 2010
Full paper	Appendix F.5
Available at	http://www.wiete.com.au/1wiete proceedings.html

This paper demonstrated the possibility of using a remote laboratory for students in a distant country such as Thailand. It introduced the online learning environment used in this research. As it was presented in Thailand, representatives of other Thai universities attended the conference and were interested in conducting cooperative research.

6. Title	State Model Diagrams – A Universal Runtime Network Management Tool
Author(s)	S. P. Maj, W. Makasiranondh, D. Veal
Journal	Modern Applied Science
ERA rank	A
Publication date	30 December, 2010
Full paper	Appendix F.6
Available at	http://www.ccsenet.org/journal/index.php/mas/issue/view/295

This paper investigated the development of SMD software, named Sopwith. It discussed the development of the software from the original paper-based SMDs.

7. Title	An evaluation of Firewall configuration methods
Author(s)	S. P. Maj, W. Makasiranondh, D. Veal
Journal	International Journal of Computer Science and Network Security, 10(8), 1-7.
ERA rank	C
Publication date	30 August, 2010
Full paper	Appendix F.7
Available at	http://search.ijcsns.org/07_book/2010_08.htm

This paper introduced the usage of SMDs in teaching the security aspects of internetworking education. It discussed the usage of GUIs in comparison with the traditional methods of CLI. It was used as a foundation of the integration of the GUI tools to the online learning environment discussed in this research and the papers mentioned earlier.

A.3 Link of publications' content to this thesis

All publications that have contributed to the internetworking education topics can be seen via the following diagram.

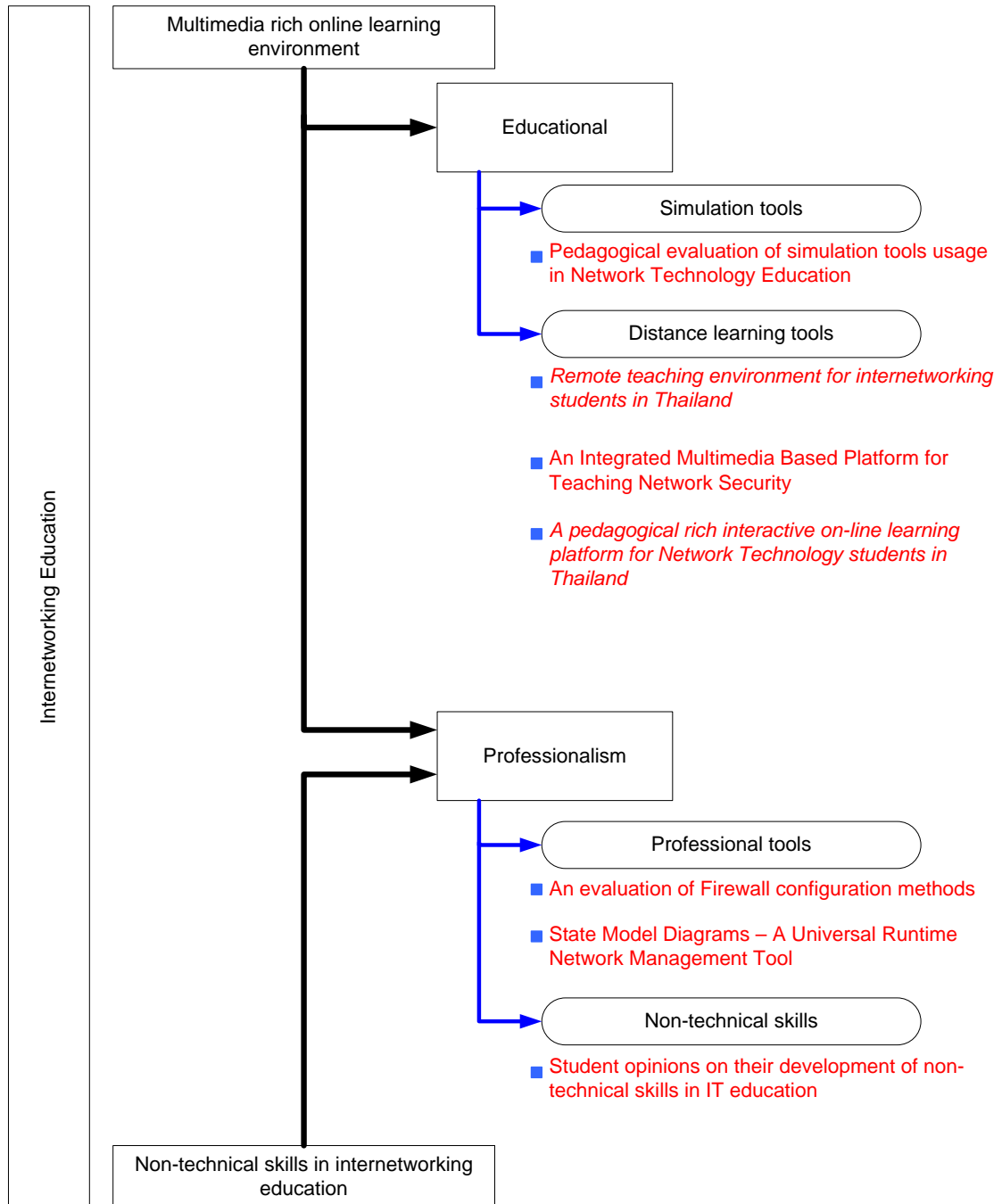


Figure 68. Publications relation to this thesis

Appendix B. Glossary of terms

Abstraction	A grouping concept, whereby a hierarchy is stuck on higher levels of abstraction placed near the top with more specific concepts underneath. According to ACM, 1991 is quoted by Veal (2003), levels of abstraction are the nature and use of abstraction in computing. The use of abstraction is managing complexity, structuring systems, hiding details, and capturing recurring pattern. This ability represents an entity or system by abstractions having difference levels of details and specificity.
Constructivism	“Constructivism is a dominant theory in education. According to this theory students construct new ideas based upon their current/past knowledge. The students select and transform information, and make decisions that are dependent upon their present schema or mental models” (Kohli, et al., 2004, p. 2).
Diagram	A diagram is a simplified and structured visual representation of concepts, ideas, constructions, relations, statistical data, and anatomy, which used in all aspects of human activities to visualise and clarify the topic. It is usually showing the relationship between several items.
EIGRP	The Enhanced Interior Gateway Protocol (EIGRP) is a Cisco proprietary routing protocol.
Open Source	The term open source describes practices in production and development that promote access to the end product's source materials. Therefore, the end product developed source code is publicly available and no longer a proprietary property of any organisation.
RIP	The Routing Information Protocol (RIP) is a distance-vector routing protocol, which employ the hop count as a routing metric.
Router	A network device, typically connected to a range of LAN and WAN interfaces, that forwards packets based on their destination IP addresses.

Routing protocol	A protocol used between routers so that they can learn routes to add to their routing tables.
SSH	A protocol that provides a secure remote connection to a host through a TCP application.
Switch	In Ethernet, a Layer 2 device that receives an electrical signal in one port, interprets the bits, and makes a filtering or forwarding decision about the frame. If it forwards, it sends a regenerated signal. Switches typically have many physical ports, oftentimes RJ-45 jacks, whereas bridges traditionally have two ports.

Appendix C. List of Acronyms

ABET	Accreditation Board for Engineering and Technology
ACL	Access Control List
ACM	Association for Computing Machinery
ACS	Australian Computer Society
AUQA	Australian Universities Quality Agency
BCS	British Computer Society
CCNA	Cisco Certified Network Associate
CCNP	Cisco Certified Network Professional
CLI	Command Line Interface
CMS	Content Management System
CNAP	Cisco Network Academy Program
DBCDE	Department of Broadband Communication and the Digital Economy
ECU	Edith Cowan University
EIGRP	Enhanced Interior Gateway Protocol
GAAs	Government Accreditation Authorities
GNS	Graphical Network Simulator
GUI	Graphical User Interface

IAU	International Association of Universities
IEEE	Institute of Electrical and Electronics Engineers
IEEE-CS	Institute of Electrical and Electronics Engineers - Computer Society
IETF	Internet Engineering Task Force
IOS	Internetwork Operating System
IP	Internet Protocol
LAN	Local Area Network
LMS	Learning Management System
MIB	Management Information Base
NBN	Australian National Broadband Network
NIC	Network Interface Card
NMS	Network Management Station
PC	Personal computer
QAF	Quality Assurance Framework
RADIUS	Remote Authentication Dial In User Service
RDP	Remote Desktop Protocol
RIP	Routing Information Protocol
SCSS	School of Computer and Security Science

SDM	Secure Device Manager
SMD	State Model Diagram
SNMP	Simple Network Management Protocol
SOLO	Structure of the Observed learning Outcome
SSH	Secure Shell Protocol
TACACS+	Terminal Access Controller Access-Control System
TCP/IP	Transmission Control Protocol / Internet Protocol
TEQSA	the Tertiary Education Quality and Standards Agency
UDP	User Datagram Protocol
URL	Uniform Resource Locator
VDO	Video
VLE	Virtual Learning Environment
WAN	Wide Area Network

Appendix D. Questionnaire of Internetworking education

Project title: An Investigation into Internetworking Education Questionnaire

This questionnaire is designed to provide information for an investigation into internetworking education. Please read the information letter as this explains intentions of this research project. Please ensure that you write your student identification number on the questionnaire which will be used as a code to identify the set of data for the research purposes only. Also ensure that you do not write your name or any other comments that could potentially identify you on the questionnaire. Before completing the questionnaire, please make sure that you have consented to take part in this research by filling in the consent form.

There are three sections in this questionnaire:

- Part A) Background of participant
- Part B) The evaluation of remote access laboratory (E-learning environment)
- Part C) The evaluation of using the State Model Diagram (SMD) application

Please specify your university name:

Part A) Background of participant

(Please complete by marking your choice in the appropriate box)

1. Is your course related to Information Technology or Computer Science?

☐ Yes, I am studying Information Technology.

☐ Yes, I am studying Computer Science.

☐ No, I am not studying either of those courses. I am studying.....

2. I am a

☐ Full-time student

☐ Part-time student

☐ Other (Please specify).....

3. Are you an off-campus student?

☐ Yes, I am. If “yes”, How far away – are you from your university campus?

.....

☐ No, I am not

4. What level of qualification are you studying?

☐ I am a postgraduate student

☐ I am an undergraduate student

5. On which year of your course are you currently enrolled?

☐ I am in the first year.

☐ I am in the second year.

☐ I am in the third year.

☐ I am in the fourth year.

5.1 Is this the last year of your course?

☐ Yes

☐ No

6. Does your university provide an internetworking laboratory facility with your course?

☐ Yes, they do. Please go to question number 7

☐ No, they do not; if “no” please give reasons and then go to Part B

.....

.....

7. What form of internetworking laboratory facility does your university provide?

NOTE: Please do not include access obtained as part of this research project.

☐ Traditional face-to-face laboratory, please specify the size of laboratory

Number of routers _____

Number of switches _____

Maximum number of students _____ in the laboratory at any one time.

☐ Simulation based laboratory, please mention the software name.....

☐ Remote access laboratory

☐ Other, please specify

8. I get all of the access to the university inter-networking laboratory that I need.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

Could you please explain your answer in more detail?

.....

Part B) The evaluation of remote access laboratory

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
9. I feel confident when learning computer networking in remote access classroom.					

Why? Please give the reasons.

.....

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Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
10. The university should use remote classrooms as a main tool for teaching computer networking?					

Why? Please give the reasons.

.....

.....

.....

.....

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
11a. When compared with the traditional hands-on laboratory , I prefer to do the lab exercises via the remote access laboratory .					

Why? Please give the reasons.

.....

.....

.....

.....

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
----------	-------------------	----------	---------	-------	----------------

11b. When compared to the simulation laboratory , I prefer to do the lab exercises via the remote access laboratory .					
---	--	--	--	--	--

Why? Please give the reasons.

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.....
.....

12. What is your preferred method for learning computer networking?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
12.1) I prefer to learn by using a traditional face-to-face laboratory more than any other type of laboratory.					
12.2) I prefer to learn by using the simulation laboratory more than any other type of laboratory.					
12.3) I prefer to learn by using the remote access laboratory more than any other type of laboratory.					
12.4) I prefer to learn just in the lecture without the necessity of practising in a laboratory					

Please give the reasons?

13. Please rate the option(s) below of your opinion on the benefit(s) of using a remote classroom in your university.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
13.1) The remote laboratory was easy to use.					

13.2) I can use this remote facility anywhere I would like.					
13.3) The laboratory provided realistic equipment responses in the experiment.					
13.4) Remote laboratory provided good accessibility to the equipment.					
13.5) Laboratory session can start immediately in the same room as lecture.					
13.6) The remote laboratory provided the ability to control different equipment from one computer screen.					
13.7) Using the remote laboratory is a more efficient use of my time than using a traditional hands-on laboratory.					
13.8) The remote laboratory has less safety hazards than a traditional hands-on laboratory.					
13.9) The remote laboratory is potentially useful for disabled students.					
Other opinions, please specify					
13.10)					
13.11)					
13.12)					

13a. Are there any other advantages of using a remote classroom that you would like to suggest? Please specify.

.....
.....
.....

14. Please rate as to what you believe are the disadvantage(s) of using a remote classroom in your university.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
14.1) Laboratory setup is confusing.					
14.2) The equipment does not respond quickly enough.					
14.3) There is a lack of necessary physical					

interaction with the equipment.					
14.4) I am often confused as to which device I am currently working on.					
14.5) A lot of the time, I worry that the physical setup at the laboratory may be different to what I understand.					
14.6) I feel limited by the fixed physical topology that I have to follow and do not have enough flexibility.					
14.7) Timely communication with the remote instructor is a major issue					
14.8) I felt disconnected from the physical reality of the devices by using the remote laboratory.					
Other opinions, please specify					
14.9)					
14.10)					
14.11)					

14a. Are there any other disadvantages of using the remote classroom that you would like to suggest? Please specify.

.....
.....
.....

15. What do you suggest should be available in a remote classroom?

.....

.....

.....

16. Please rate these following statements based upon your experiences of using the remote access laboratory.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
16.1) The remote instructor can look after you more effectively in the remote laboratory session than if the same instructor were in the same lab with you.					
16.2) I can focus upon configuring the equipment without the need to setup the physical connections.					
16.3) I still prefer to learn computer networks in a conventional face-to-face laboratory.					
16.4) Remote laboratory access and study is more convenient than using a conventional laboratory.					
16.5) I still need a local instructor to be with me even though the remote instructor was there to help during the remote lab time.					
16.6) There is more freedom working with remote instructor without supervision from a local instructor.					
16.7) It would be more convenient for me if the remote facility had a booking system.					
16.8) It would be more convenient for me if it is available 24/7.					
16.9) It would be more convenient for me if the remote access laboratory provided a graphical user interface where by I could click on the icon of a device within a network topology diagram to gain access to configure that device.					
16.10) It would be more convenient for me to be able to save my configurations so that I can return to a laboratory exercise at a future session.					

16.11) It would be useful to have the convenience of remote access laboratory available 24/7 even when a traditional hands-on laboratory is provided.					
---	--	--	--	--	--

Why? Please give the reasons. (Please note the question number that you are referring to)

17.) Please give reasons of why you need or don't need a **local instructor** to be with you during the remote laboratory session.

18.) Please give reasons of why you need or don't need a **remote instructor** to be with you during the remote laboratory session.

Part C) The evaluation of using SMD application

19. What is your preferred method for studying networking technology in a remote classroom environment?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
19.1) Text-based Command Line Interface (CLI) only					
19.2) Text-based CLI with a webcam showing in real time the networking equipment					
19.3) Text-based CLI and SMDs running simultaneously					
19.4) Text-based CLI and SMDs with a webcam showing in real time the networking equipment					

Please give the reasons.

Question	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
20. The university should use SMDs as a main tool for teaching computer networking in the future?					

Why?

.....

.....

.....

.....

...

21. The SMD helps you to do the following tasks.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
21.1) Memorize the content of the course					
21.2) Understand by visualizing the diagram that SMDs provide					
21.3) Understand the concept of networking without memorizing different commands					
21.4) Focusing upon the result and content of the laboratory exercise without needing to be concerned with the input and output of appropriate CLI commands.					
21.5) SMDs help me to retain the knowledge that I get from the laboratory.					
21.6) The responses of SMDs in the laboratory makes me understand the content.					
21.7) SMDs encourage me to learn.					
21.8) SMDs allow me to focus on learning to configure the network equipment without					

losing track by needing to check the result of commands at the same time.					
---	--	--	--	--	--

22. Would you like to give any comment on the disadvantage of SMDs? Please specify.

23. SMDs with a remote access laboratory

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
23.1) SMDs are helpful for me to learn in the remote laboratory situation.					
23.2) SMDs assist the learning process in the remote access laboratory.					
23.3) SMDs help me to gain confidence in device configuration as I can actually see the results from the diagrams that SMDs provide.					

Please give the reasons.

24. Do you have any suggestion when using SMDs in a remote laboratory? Please describe.

25. Overall evaluation of SMDs

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
25.1) The user interface of the SMD software was easy to use					

25.2) The response of the SMD software is fast enough to be used effectively.					
25.3) To be able to modify network configuration directly via the SMD software would help my learning.					

Please give the reasons.

26. Please note any further comments that you may wish to add (if any) about the above topics.

.....

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.....

27. Were there any other questions that you believe would have been useful for us to ask, but were not included? If so what questions were they?

Thank you for your participation

Appendix E. Questionnaire of Soft skills

Project title: Student perspective on workplace technical and non-technical skills development in internetworking education

Questionnaire

This is an **anonymous questionnaire** and was designed to collect information for research related to an investigation of technical and non-technical skills in internetworking education. Please read the Information letter carefully as this explains the intentions of this research project. Participants completing the paper-based version of the questionnaire should not write their names or any comments that may identify them to the research team. By completing the questionnaire, you are consenting to take part in this survey stage of the research.

There is an additional part of this research which will involve an interview. This interview activity is a separated study from this questionnaire. Please read the information letter carefully and contact the researcher, if you wish to take this additional part of interview. For your information a list of the interview questions have been provided in the last section of this questionnaire.

There are 5 sections of this questionnaire.

<u>Part</u>	<u>Page number</u>
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Part 2 Soft skills in general	5
Part 3 Identifying existing soft skills	9
Part 4 Identifying the source of soft skills	10
Part 5 Communication skills.....	12
Interview questions	13

Part 1 General questions

Please choose an appropriate answer that describes you the most clearly.

1. What level is your course?
 - a. Bachelor
 - b. Graduate Diploma
 - c. Graduate Certificate
 - d. Masters
 - e. Doctorate
 - f. Other, please specify _____
2. What kind of course are you enrolled in?
 - a. A degree by Coursework
 - b. A degree by Research
 - c. Other, please specify _____

3. What course are you enrolled in?
- a. Bachelor of Information Technology (U67)
 - b. Bachelor of Computer Science (U65)
 - c. Bachelor of Science (Networking Science) (K87)
 - d. Graduate Certification in Network Technology (U38 or V27)
 - e. Graduate Diploma of Network Technology (S13)
 - f. Graduate Certificate in Information technology (745 or F06)
 - g. Master of Games and Simulation Programming (I47)
 - h. Master of Network Technology (I38)
 - i. Master of Science (Computer Science) (I39)
 - j. Master of Computer Science (I45)
 - k. Master of Information Technology (I46)
 - l. Doctor of Information Technology
 - m. Other, Please specify _____

4. What year of study are you in?
- a. First year or single year program
 - b. Last year
 - c. Short program (less than 1 year)
 - d. Other year, please specify _____

5. Do you consider your self as a full time or a part time enrolled student?
- a. Full time
 - b. Part time
 - c. Other, please specify _____

6. In what percentage you consider yourself as an On campus student? Please answer by specify an approximate percentage of units that you enrol to be studied On campus.

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Percentage of units enrolled to be studied On campus	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

7. Other _____ please _____ specify.

Please list the units that you have already completed.

8. Please specify the unit(s) that you are currently enrolled in this semester.

9. Could you specify your age in the given range in years?

- a. 0 – 18
- b. 19 – 22
- c. 23 – 26
- d. 27 – 30
- e. 31 – 34
- f. 35 – 40
- g. 41 – 44
- h. 45 – 48
- i. 49 - 52
- j. Over 53

10. Have you had any previous work experience?

- a. Yes
- b. No

11. How many years of work experience which equivalent to full-time work, do you have? (please specify)

_____ years _____ months

12. How many years of this work experience related to the IT or computer field?

_____ years _____ months

13. How many years of work experience do you have related to computer networking?
_____ years _____ months

14. Could you please specify your main area of work?

- a. Computer Network related work
- b. Computer Software related work
- c. Computer Database related work
- d. Other, please specify _____

Part 2 Soft skills in general

Soft skills or non-technical skills are skills apart from technical knowledge that you have learned from normal engineering and science textbooks or courses. These skills are, for example, communication skills, emotional intelligence, project management skills and many more. Such skills can be critical for some jobs, especially if they involve dealing with customers who have no technical background. For example, good practice in communication skills may help a technical person understand more of customer requests, expert practice in emotional intelligence skills means someone can behave well in a difficult situation, and so on.

These are some brief definition of some well-known soft skills.

Communication skills: an ability to communicate with other people with different backgrounds, verbally and non-verbally.

Leadership skills: a skill to coordinate, persuade and motivate the people in a team to function fully and complete joint tasks. Sometimes leadership skills relate to how to use authority as well as being assertive.

Working in teams: the process of working collaboratively with other people to reach the same goals.

Emotional intelligence: an ability to learn and recognize people's emotional states in order to minimise any impulsive or unpleasant behaviour.

This section of the questionnaire seeks to collect your opinions about many aspects of these skills.

Please rate yourself in the appropriate agree or disagree box.

15. You feel that the current course that you are undertaking builds your soft skills?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

16. What soft skills do you think an employer will require from you?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
16.1) Communication skills					
16.2) Leadership skills					
16.3) Working in teams					
16.4) Emotional intelligence					
Other skills please specify					
16.5) _____					
16.6) _____					
16.7) _____					

17. What are the soft skills development opportunities you think the university, especially in internetworking units, should provide for you?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
17.1) Communication skills					
17.2) Leadership skills					
17.3) Working in teams					
17.4) Emotional intelligence					
Other skills please specify					
17.5) _____					
17.6) _____					
17.7) _____					

18. What do you think will be the best mode of delivery for skills units?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
12.5) I prefer to learn soft skills in the classroom.					
12.6) I prefer to learn soft skills via an online course					
12.7) I can learn it from online facility such as Skype					
12.8) I prefer to learn soft skills from taking part in a play acting scenario					
12.9) I prefer to learn soft skills from a near real life project or practice project					
I prefer to learn in a different way. (Please specify)					
12.10) _____					
12.11) _____					
12.12) _____					

19. If you had a chance to create a new internetworking curriculum, would you like to include some dedicated soft skills units?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
19.1) I prefer to have only ONE unit dedicated to soft skills for the entire study period.					
19.2) I prefer a chain of continuous units that run consecutively through out my course.					
19.3) I prefer to be taught these soft skills during the normal classroom session of normal technical units.					
19.4) I prefer the project units to challenge me into building some soft skills.					
19.5) I would have learnt soft skills myself and am not interested in learning them from any university units.					

20. In your opinion, as a student, what percentage of the current coursework in which you are enrolled contributed to building your soft skills?

0%	25%	50%	75%	100%

21. In your opinion, as a student, you think that the current portion of soft skills teaching is enough for you to build your soft skills?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

22. In your opinion, as an employer, what percentage of soft skills do you expect from new employees compared with their internetworking technical skills?

0%	25%	50%	75%	100%

23. Please identify the soft skills that are familiar (you heard about them before)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
23.1) Communication skills					
23.2) Leadership skills					
23.3) Working in teams					
23.4) Emotional intelligence					
Other skills please specify					
23.5) _____					
23.6) _____					
23.7) _____					

Part 3 Identify existing soft skills

This section of the questionnaire is designed to measure your opinion of a variety of soft skills.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
24. People in my project team can verbally understand me well.					
25. People in my project team can understand me well when I use non-verbal signals.					
26. I feel confident when communicating with my lecturers.					
27. I feel confident to communicate with clients in the real work environment.					
28. I feel that I can lead other team members to conduct group work.					
29. I prefer to follow other team members' decisions, regardless of my own opinion.					
30. I listen to every opinion of my team members before making the decision.					
31. I prefer not to work in a team.					
32. I feel more confident working alone.					
33. I feel more comfortable working with other people.					
34. I want to work with other people with different backgrounds.					
35. During project work, I prefer to work only with friends I've known previously.					
36. I am prepared to take responsibility for any group decision that my team members make, even if it is in conflict with my own opinion.					
37. I feel I can persuade people in my team to believe in my decisions.					
38. I don't want to express my own opinions when it comes to group decisions.					
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
39. I don't think a professional approach is					

necessary as we are still students.					
40. I have always compared my work to the professional standards.					
41. I feel that other people in my team cannot understand me well enough.					

Part 4 Identify the source of the skills

42. Please rate the sources from which you believe you have learnt soft skills.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
42.1) Schools					
42.2) Work experiences					
42.3) University study					
42.4) Family					
42.5) Friends					
42.6) Social activities					
42.7) Project in the current university courses					
42.8) Normal unit in university courses					
42.9) Group work with other students					
42.10) Group work within project units					
42.11) External training apart from university					
Other, Please specify					
42.12) _____					
42.13) _____					
42.14) _____					

43. Source of the skills: You have learnt these following skills from your previous experience **outside** this university?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
43.1) Communication skills					
43.2) Leadership skills					
43.3) Working in teams					
43.4) Emotional intelligence					
Other skills, please specify					
43.5) _____					
43.6) _____					
43.7) _____					

44. Source of the skills: You have learnt these following skills from **this university**?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
44.1) Communication skills					
44.2) Leadership skills					
44.3) Working in teams					
44.4) Emotional intelligence					
Other skills, please specify					
44.5) _____					
44.6) _____					
44.7) _____					

Part 5 Communication skills

This part focuses particularly upon Communication skills

45. Do you think the current networking curriculum helps you to build overall communication skills?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree

46. Do you think the current networking curriculum helps you to build the following specific communication skills?

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
46.1) Oral communication					
46.2) Presentation					
46.3) Written communication					
46.4) Listening skills					
46.5) Reading skills					
Other, please specify					
46.6) _____					
46.7) _____					
46.8) _____					

Are there any questions that we have not asked you about soft skills? Please give us suggestions for any further questions we should ask.

Interview questions include as open ended questions

These questions are those that will be asked during the interview should you wish to participate.

1. What are the most difficult experiences that you have found during your project?
Please identify the soft skills you can gain from working in projects.
2. Do you think the current internetworking curriculum contributes to build your soft skills?
 - a. If so how?
3. What are your opinions of the technical content of the current internetworking curricula?

Thank you

