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World Class Curriculum – on a budget

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ABSTRACT

Universities must compete in an increasingly difficult global market place. In order to successfully do so they must identify and profile market segments in order to achieve a unique selling position. Partnering may provide only part of the solution. The Cisco Network Academy Program (CNAP) is the world's largest network curriculum developed at an initial cost of US\$75 million. There are advantages to becoming a Cisco academy such as access to on-line curriculum and low cost equipment. However, with over 10,000 Cisco academies world wide it is difficult to achieve a marketing advantage. Cisco provides low cost equipment but academies are responsible for laboratory design. Accordingly, a state-wide, national and international analysis was conducted of Cisco academy laboratories and hence two new laboratories designed and commissioned. These laboratories have been independently recognized to be of international standing. Significantly, other laboratories investigated were better equipped. Secondly the Cisco curriculum was analysed and found to lack a coherent and uniform pedagogical framework. A new diagrammatic model, State Model Diagrams (SMDs), was therefore designed. Curriculum based on SMDs was implemented and evaluated. Extensive evaluations of students taught using SMDs clearly resulted in better learning outcomes than those achieved by the standard Cisco curriculum. Furthermore, as a diagrammatic technique SMDs are substantially language independent – confirmed by a detailed analysis of overseas students taught using SMDs. By invitation, this research was presented to Cisco educational experts at the annual Cisco Asia/Pacific conference. The feedback was excellent. The initial trials of curriculum based on SMDs are now being extended internationally. All research to date (eleven publications), and feedback from Cisco Asia/Pacific strongly indicates that SMDs has the potential to be used as the pedagogical basis of the CNAP curriculum and hence affect the learning experience of over 500,000 students in more than 10,000 academies.

INTRODUCTION

In 2001 the ACM/IEEE Computing Council introduced Net-Centric Computing in the Computer Science Undergraduate Body of Knowledge (Tucker et al., 1991). There are different but equally valid approaches to teaching networking – quantitative (i.e. engineering based); algorithmic (i.e. computer science). According to Kurose , 'Among the approaches towards networking curricula, one finds the more quantitative (electrical engineering) style of teaching networking versus a more software/algorithmic (computer science) approach, the more "hands-on" laboratory based approach versus the more traditional in-class lecture based approach; the bottom-up approach towards the subject matter versus a top-down approach.'. There is an alternative approach based primarily on employer expectations – the vendor based Cisco Network Academy Program (CNAP). The CNAP provides not only vendor specific curriculum and certification (Cisco Certified Networking Associate (CCNA) and Cisco Certified Networking Professional (CCNP)) but also low cost equipment (hubs, switches, routers, wireless access devices etc). The CNAP is based upon an educational web site that cost US\$75 million to develop and an extensive repertoire of Cisco sponsored textbooks.

Based on a market analysis of employer expectations this university elected to implement this vendor-based, “hands-on” approach to curriculum (Abelman, 2000). It should be noted that vendor-based education has both strengths and weaknesses; critics and advocates (Maj, 2003).

The CNAP is a global curriculum with numerous advantages that include: international de facto standard in network certification; practical, ‘hands-on’ curriculum aimed at producing ‘industry ready’ students; access to low cost equipment; on-line curriculum that is regularly updated; on-line assessments etc. It should be noted that to offer Cisco curriculum an institution must become a Cisco Network Academy. This is a quality assurance standard, mandated by Cisco, to ensure that the institution has the appropriate equipment to support the Cisco curriculum. Furthermore all staff teaching this curriculum must be appropriately qualified and trained to the Cisco standard. This mandatory training to a specific standard represents an additional cost for institutions but ensures that the Cisco curriculum is an international standard. It should be noted that this is a recurrent cost – a major change in the academy curriculum (perhaps every 5 years) requires certified retraining.

There are potential disadvantages to becoming a Cisco Network Academy that include: the need to purchase network equipment; mandatory and regularly staff training to the Cisco standard; the need to upgrade equipment when the curriculum changes, maintenance of your Cisco Academy etc.

In the final analysis there are over 10,000 Cisco academies world wide with over 400,000 students enrolled in the Cisco academy programs.

Educational institutions must increasingly compete in within an international context. Whilst there are advantages to becoming a Cisco Network Academy operating in such a global endeavor it is problematic to achieve a marketing niche and associated marketing advantage. In order to achieve a marketing advantage we adopted the strategy to achieve a ‘world class’ standard for our Cisco networking laboratories and curriculum – all within a relatively modest budget.

MARKET ANALYSIS – CISCO NETWORKING LABORATORIES

Universities, both within Australia and worldwide, are able to purchase low cost equipment from CNAP. However universities are responsible for laboratory design. In order to differentiate this university from other universities not only nationally but also internationally, and hence obtain a marketing advantage, we conducted a state-wide, national and international analysis of Cisco based networking laboratories. There are a wide range of laboratory configurations.

Some laboratories made use of standard computer science teaching rooms for teaching networking. In these laboratories the networking equipment was mounted on mobile trolleys and taken into and out of the rooms as needed. This provided the advantage of not having to have a dedicated network room (i.e. allowing multiple use rooms), however there were significant issues with respect to cabling between devices; technical support overheads; potentially increased damaged to networking equipment etc. An alternative approach was to have a dedicated network room. Institutions employing this design adopted a number of different approaches. At one institution the network equipment (switch, router etc) was located at each student work space – typically shared by two students.

Based on this analysis of different network laboratories we designed our own configuration located in dedicated rooms. We provide student work places with only PCs. Connectivity between adjacent PCs is provided by connecting these PCs to cabling to a central collection of equipment. This cabling is external to the wall, rather than being behind, hence it can then be used for teaching purposes. The central collection of networking equipment is housed in industry standard 19 inch telecommunication racks. Each pair of students has access to their own networking devices that include: single patch panel, two routers, one PIX firewall, one wireless access point and two un-managed switches. In addition to this there are two Wide Area Network (WAN) emulators and a 7 port PIX firewall. Each 19 inch telecommunications rack holds two groups of equipment. There are five racks – hence equipment for 20 students. All the racks are adjacent and hence allow for quick

and easy connectivity not only between the different devices belonging to one student pair but also between equipment belonging to another student pair. In effect it is relatively simple to build a very large network using the different devices in all the five racks. All equipment in the racks is protected by uninterruptible power supplies with surge protection. These dedicated network teaching laboratories were commissioned on time and on budget.

Even though there are other better equipped laboratories these laboratories have been independently recognized to be of international standing. According to the Cisco regional academy manager, David Zanich, 'Your CCNA lab has set a benchmark for its kind here in WA'. Certainly, other universities may have more equipment in their laboratories but our design is considered superior. We did not get the best simply by spending the most. According to Professor Tony Watson, Pro Vice Chancellor (Technology and Information Services), 'The Cisco laboratories have been described as world class and are located on the Mt Lawley campus.'

In order to help offset the cost of these laboratories they are used not only for teaching the Cisco curriculum but also other, non-Cisco networking units. The laboratories are also extensively used by research students. It should be noted that because Cisco Academies are able to purchase low cost devices they are therefore not allowed offering commercial (full fee) training courses.

MARKET ANALYSIS – NETWORK TECHNOLOGY CURRICULUM

Using this equipment we conducted an extensive analysis of the Cisco curriculum. Two main problems were found. Firstly, this curriculum primarily teaches internetworking device (routers and switches) functionality using the command line interface (CLI) in conjunction with various software diagnostic tools such as the Cisco Discovery Protocol, PING, TRACE, IP ROUTE and also Telnet. The CLI allows the user to determine and modify the status of the various components of a router such as routing table entries, Address Resolution Protocol (ARP) table entries, interface status etc. However, the hierarchical CLI commands may require considerable technical expertise. Furthermore the status information of the many different devices, interfaces and associated protocols etc must typically be obtained by a number of different CLI commands. This may be problematic during the teaching process when it is necessary to integrate all of this information from a number of different CLI commands. It should be noted however that for experienced network engineers the CLI is a very powerful and useful tool.

Secondly, it was found that the CNAP on-line curriculum did not provide a coherent, diagrammatic, conceptual model of internetworking devices. In order to further check this large selection of Cisco sponsored textbooks and also non-Cisco textbooks were analysed. It was found that internetworking devices are typically considered as 'black boxes' by introductory Cisco endorsed textbooks and introductory non Cisco endorsed textbooks. The search was extended to Cisco endorsed switching books and non-Cisco endorsed switching books; Cisco endorsed textbooks on routing and non Cisco books on Routing; remote access books and finally both general and specialized books on networking - all with the same result (Maj et al., 2004). It should be noted that Cisco use finite states to explain neighbor acquisition in BGP, route acquisition in EIGRP and also neighbor and route acquisition in OSPF. However this is not integrated with router management at the CLI interface.

A good case could therefore be made for a new tool to assist in teaching network technologies.

PEDAGOGICAL CONSIDERATIONS

If students are not provided with a conceptual model they are likely to construct their own which is likely to be inconsistent, incomplete and incorrect. According to von Glasersfeld, 'Put in the simplest way, to understand what someone has said or written means no less but also no more than to have built up a conceptual structure that, in a given context, appears to be 'compatible' with the structure the speaker had in mind. – and this compatibility, as a rule,

manifests itself in no other way than that the receiver says and does nothing that contravenes the speaker's expectations.' (von Glasersfeld, 1989).

Significantly, even if a conceptual map is not provided to students learning may appear to take place. As noted by Mestre,

'What is deceptive is that students will often display 'understanding' in standardized science tests, in tests constructed by teachers, or in text-embedded tests provided by textbook publishers, thereby giving teachers a false impression of their student's true understanding. Tests that probe for factual knowledge or that do not force students to apply the concepts covered in class will continue to show that students 'understand' the material covered in class.' (Mestre, 1994).

Within a university context students' understanding may therefore be more related to memory rather than understanding (Bjork, 1978) (Hiebert and Carpenter, 1992). A conceptual model should provide the foundation for a student to develop a rich understanding. According to Reeder, 'The problem is many teacher mistake signs of apparent understanding for true understanding. For example, students using the right words and definitions, manipulating formulas correctly, or answering questions with borrowed options give the impression that they understand. And in fact they may, since someone with understanding can do those things, but it is also possible to do them without understanding. Therefore, it is simply not safe for a teacher to infer understanding from those types of responses. As it turns out, the degree to which students' grasp a concept can be reliably inferred only when they can somehow apply the concept in an authentic context.'

However, it should be noted that the ability to recall and explain a concept does not necessarily translate to understanding, nor does it guarantee that students can apply and use the concept in a meaningful way (Julyan and Duckworth, 1996).

The ACM/IEEE Computing Curriculum 2001 included Net-Centric Computing in the Computer Science Undergraduate Body of Knowledge (Tucker et al., 1991). Within this curriculum abstraction is identified as a key process in research, development and applications work. Furthermore, abstraction is listed as one of twelve recurring concepts fundamental to computing:

"Levels of abstraction: the nature and use of abstraction in computing; the use of abstraction in managing complexity, structuring systems, hiding details, and capturing recurring patterns; the ability to represent an entity or system by abstractions having different levels of detail and specificity. Examples include levels of hardware description, levels of specificity within an object hierarchy..."

Models are based upon abstraction. According to Gilbert,

'A model is a simplified representation of a system, which concentrates attention on specific aspects of the system, Moreover, models enable aspects of the system, i.e. objects, events, or ideas which are either complex, or on a different scale to that which is normally perceived, or abstract to be rendered either visible or more readily visible.' (Gilbert, 1995)

The importance of a diagrammatic model as an aid to student learning is illustrated by Thomas, 'The use of diagrammatic representation provides an alternative to just offering more words, which may only compound their difficulties.' (Thomas, 2000)

MODELLING – TOOLS AND TECHNIQUES

Models, based on abstraction, are therefore a means of controlling detail. Ideally models should be: diagrammatic, self-documenting, easy to use and allow hierarchical top-down decomposition to control detail. Leveling is the property by which complex systems can be progressively decomposed to the level that is meaningful whilst still maintaining consistent links to other levels.

There exist a wide range of modeling methods each with its own strengths and weakness. Modeling characteristics considered of particular importance in this application are: diagrammatic, ease of use, ability to control detail by means of hierarchical top down decomposition and also the

integration of the status of the different components of a router. According to Cooling, there are two main types of diagram: high level and low level. High-level diagrams are task oriented and show the overall system structure with its major sub-units. Such diagrams describe the overall function of the design and interactions between both the sub-systems and the environment. The main emphasis is 'what does the system do' and the resultant design is therefore task oriented. By contrast, low-level diagrams are solution oriented and must be able to handle considerable detail. With low-level diagrams the main emphasis, applicable to this application, is 'how does the system work'.

STATE MODEL DIAGRAMS – A NEW TOOL FOR TEACHING NETWORK TECHNOLOGY

We analysed a wide range of different modeling techniques and proposed State Model Diagrams (SMDs) for modeling switches, routers and the associated protocols (Maj and Kohli, 2004a). Using a single SMD it is possible to manually extract from the different CLI outputs only the data directly relevant to device status and hence succinctly describe device operation. It was found that,

'Using the state diagrams for the internetworking devices switch and router it is possible to capture on a single diagram the information from a number of different hierarchical CLI commands. Furthermore the diagrams can be used to represent state information that may not be explicitly provided by the CLI e.g. ARP states free, pending and resolved. The diagrams also include the OSI and TCP/IP layers. It is therefore possible to clearly see which protocols operate in which layer.' (Maj et al., 2004)

By example, in order to determine the operation of a router key information needed includes: interface IP and MAC addresses; interface line status; interface line protocol status; ARP details and routing table entries. This information is typically obtained from four CLI commands – show interface fa0/1, show interface fa0/0, show arp and show ip route. Actual output, from an operational router, for some of these CLI commands is as follow:

Router1#show interface fa0/1

```
FastEthernet0/1 is up, line protocol is up, Hardware is AmdFE, address is 000c.30e2.e501 (bia
000c.30e2.e501), Internet address is 192.168.1.1/24, MTU 1500 bytes, BW 100000 Kbit, DLY 100
usec, reliability 255/255, txload 1/255, rxload 1/255, Encapsulation ARPA, loopback not set,
Keepalive set (10 sec), Full-duplex, 100Mb/s, 100BaseTX/FX, ARP type: ARPA, ARP Timeout
04:00:00, Last input never, output 00:00:09, output hang never, Last clearing of "show interface"
counters never, Input queue: 0/75/0/0 (size/max/drops/flushes); Total output drops: 0, Queueing
strategy: fifo, Output queue: 0/40 (size/max, 5 minute input rate 0 bits/sec, 0 packets/sec, 5
minute output rate 0 bits/sec, 0 packets/sec, 0 packets input, 0 bytes, Received 0 broadcasts, 0
runts, 0 giants, 0 throttles, 0 input errors, 0 CRC, 0 frame, 0 overrun, 0 ignore, 0 watchdog, 0 input
packets with dribble condition detecte, 68 packets output, 8770 bytes, 0 underruns 0 output errors,
0 collisions, 2 interface resets, 0 babbles, 0 late collision, 0 deferred, 3 lost carrier, 0 no carrier, 0
output buffer failures, 0 output buffers swapped out
```

Router1#show arp

Protocol	Address	Age (min)	Hardware Addr	Type	Interface
Internet	192.168.2.2	1	0012.01a1.cda1	ARPA	FastEthernet0/0
Internet	192.168.1.1	-	000c.30e2.e501	ARPA	FastEthernet0/1
Internet	192.168.2.1	-	000c.30e2.e500	ARPA	FastEthernet0/0

Router1#show ip route

Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B – BG, 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, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area, * - candidate default, U - per-user static route, o - ODR, P - periodic downloaded static route. Gateway of last resort is not set

C 192.168.1.0/24 is directly connected, FastEthernet0/1

C 192.168.2.0/24 is directly connected, FastEthernet0/0
 R 192.168.3.0/24 [120/1] via 192.168.2.2, 00:00:03, FastEthernet0/0

A single SMD can be used to represent the main data extracted from these four separate CLI commands all linked to the appropriate OSI level (Figure 1). Including the OSI and/or TCP/IP layers clearly illustrates to students that, for example, MAC addresses and Line Protocols are associated with the OSI layer 2, Datalink Layer.

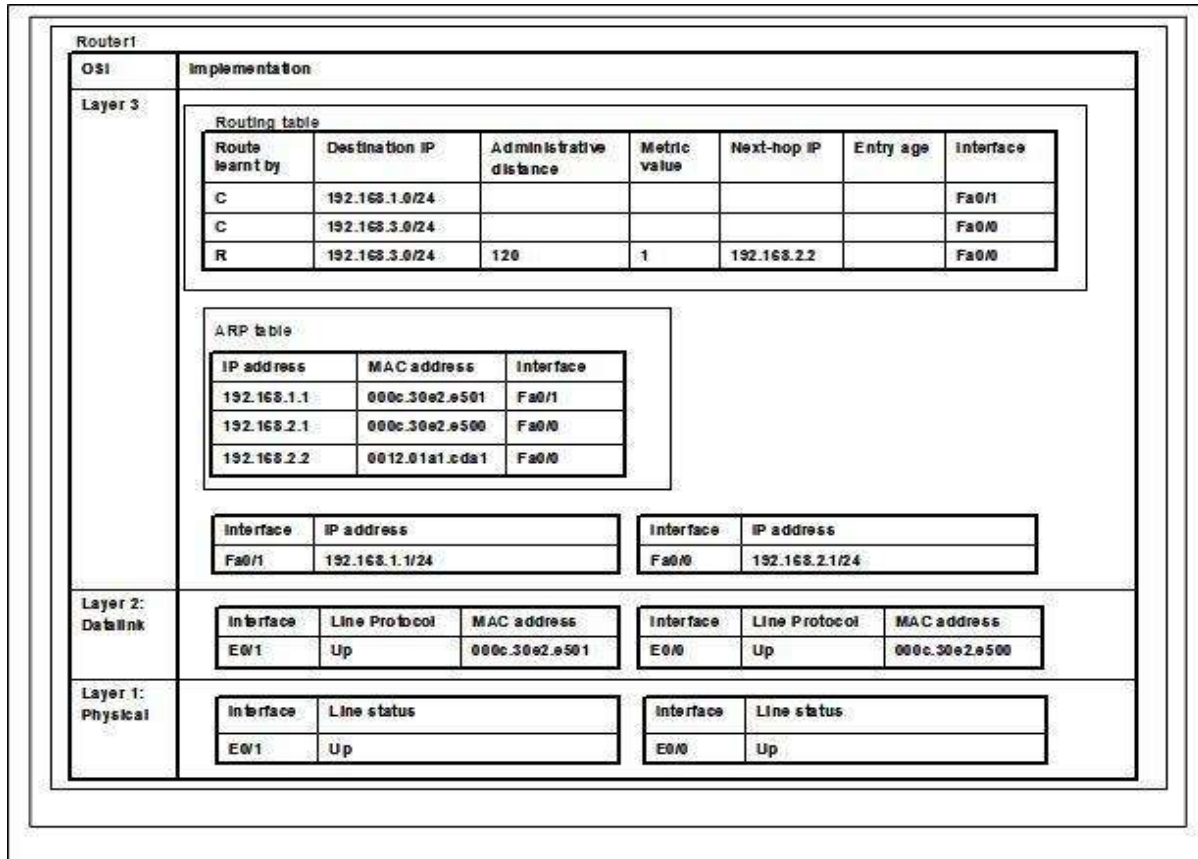


Figure 1 – State Model Diagram of a router

It is possible to apply the same basic principles to other routing protocols,

‘Furthermore the modularity allows one to have a basic model (e.g. a router running the RIP routing protocol) whose functionality can be enhanced by the inclusion of additional state tables. Hence the router state model can be used for all the main Interior Gateway Protocols – distance vector (Interior Gateway Routing Protocol – IGRP), link state (Open Shortest Path First – OSPF) and balanced hybrid (Enhanced Interior Gateway Routing Protocol – EIGRP). (Maj et al., 2004).

In effect students do not have to learn a new conceptual model, rather they can build upon and extend their existing knowledge i.e. capturing recurring patterns. In this context new knowledge reinforces existing knowledge. However using the diagrams it is possible to selectively including and exclude details (i.e. hiding details) whilst maintaining the conceptual integrity by means of hierarchical leveling,

‘The highest level (level 0) module is a single diagram that describes the entire system. Subsequent diagrams are expansions of this level 0 diagram and are numbered accordingly. Furthermore, all diagrams must be linked thereby allowing navigation between them.’ (Maj et al., 2004)

STATE MODEL DIAGRAMS – EVALUATION AS A NEW TEACHING TOOL

The state model diagrams were used as the pedagogical foundation of non-Cisco network technology units and the results evaluated. It was found that,

‘Postgraduate students, whose learning was based upon the state models, demonstrated a comprehension of devices comparable to a qualified and experienced expert in this field. Furthermore these students performed significantly better than other students both within the same and a different institution.’(Maj and Kohli, 2004b).

Further work also supported these findings (Kohli et al., 2004). These initial studies were extended in order to measure the change in learning throughout an entire semester for students taught using standard curriculum and those taught using curriculum based on the state model diagrams. The results strongly suggest the models significantly enhance learning,

‘This indicates that both groups of students learnt the required material equally well. However, from the diagrams of the state model students it can be inferred that they have richer conceptual understandings and these are aligned with those of the expert. Consequently they will be more able in future learning to progress towards the end state of the expert’s understanding. They are more likely to retain learnt material as this material is linked to more and better concepts thus enhancing recall.’ (Maj et al., 2005)

Using the state model diagrams it is possible to reinforce learning by linking abstract concepts to concrete experiences. As a formal assessment tool work to date suggests it is valid, reliable and practical (Kohli et al., 2005).

It is not uncommon for Universities to deliver curriculum to international postgraduate students whose first language is not English. However, the state model diagrams are essentially language independent. The state model was used as the basis of network curriculum taught, on shore, to postgraduate units primarily consisting of students from India and China. One unit assumes no prerequisite knowledge of the field but is a prerequisite to the second unit. It is possible for students to study both units concurrently but only after being appropriately advised. The emphasis on the first unit is how does a switch work and how does a router work. The state diagrams were used to show encapsulation, frame movement, decapsulation and protocol state changes in the three different devices – PC, switch and router. In the second unit the state model was used to teach more advanced concepts such as: Spanning Tree Protocol (STP), Virtual Local Area Networks (VLANs), Open Shortest Path First (OSPF) etc. In both units the state model is used in both the lectures and as an integral part of the workshop exercises. Surprisingly even the students with qualifications and experience in networking elected to study both units.

In keeping with university policy these units were independently evaluated. Both units scored either the highest or amongst the highest in the School, Faculty and University. These surveys are of a generic nature focusing on broad educational issues. In order to obtain further details ten overseas students, from a class of about thirty, volunteered to provide detailed feedback and critical evaluations. The anonymous comments submitted by the students, verbatim, are as follows:

Student 1: ‘you have produces a high level of teaching stuff which I have never found in any course in my life. I have done many courses on Cisco, CCNA, A+ and MCSE in country. I have studied many Cisco, Sybex, Syngress, Addison-Wiley, Congress, Prentice-Hall press books, Thompson/Pearson too, but I didn’t understand many Internet work Technology. On the other hand, when I stared to attend your lecture classes, I realise and understand what is happening inside network technology. The way you taught us and developed your lecture sheets is just unique. I last 3 months I have understood those things which I have been trying to understand for the last 2 years (really surprised me). Let me describe of some advantages doing this unit:

Your PowerPoint slides draw maps in mind, so that no one will forget what he/she learned.

Your drive inside the technology: e.g.: what really happening inside the network? Which, I believe no one revealed/explained before, like you did.

Student 2: 'I have worked in three different countries and my employers have all been best world known in there field. With my work experience with the best companies, I, feel (name removed) teaching technical is unique and very effective and result oriented. A ray of confidence is started to show up in me, which did not happen even after working for the best companies. It was nothing new, but it was all so fresh and having the man him self in front of you is just the best way to get the networking knowledge. The major part of the lectures is the way, (name removed) places the tables and diagrams it looks like a "Bible of networking" has also looked at Cisco material which is great and very graphical to make you understand the process. I, still feel the lecture material developed by (name removed) makes more sense as they tell you every thing in just the same page.'

Student 3: 'the lecture material provided my you is gr88 and is one of a kind you cant find it in any of the regular books which do not talk about the networking about arp, switches, hubs and the lecture notes have made it very easy for me to understand the networking subject and I have enjoyed it very much.'

Student 4: 'I did my CCNA and CCNP certifications in India in the year 2000. Currently I am doing the networking units co-ordinated by (name removed) at (name removed). The method he follows to teach the networking principles makes the whole concept simpler and I am able to get a better holistic picture of the series of events when we configure the different networking devices. Rather than understanding the commands for different scenarios, he gives emphasis in teaching what the cause of the scenario is and how to handle the scenarios. As some as we come across a crisis, we are able to picturise the event since he follows a diagrammatic method. To brief, I am building up my foundation real hard and strong.'

Student 5: 'Just a note to let you know how I found your diagrammatic method of teaching. It's a great concept! Human brain remembers objects better than words. Also we all know that "pictures speak a thousand works". Most of the material you covered was new to me.'

Student 6: 'it was regarding your material, to me it was easy to read and to study the whole lot at the exam time because it was all piratically mentioned, I think your unit makes a student not only concept wise but also practically efficient too'.

Student 7: 'Your diagrammatic approach makes it easy for us to understand and also to keep the data without any confusion. Also this approach saves more time instead of studying theoretically.'

Student 8:'Yes definitely I would say that the diagrams that were used by you in teaching a few concepts of CSG5206 were very useful.'

Student 9: 'Well my suggestion is that your material the diagram needs to be drawn and explained properly, though they are don in nice way without proper presentation they are difficult to understand especially for those who have not attended your lecture. This I got from one lecture of MICROPROCESSOR, which I have missed that lecture and I was preparing for my exam and you know the time for preparing that chapter equals with time for preparing all the other chapters. I got confused with 2 or 3 diagrams. That's it. Nothing else. It was very nice unit and very interesting. I liked it a lot.'

It can be seen that of the ten volunteers, nine responded with positive replies, one was positive but had reservations and the tenth did not reply. Significantly, some students had little or no knowledge of networking; others not only had successfully completed professional certification but also had worked in the field. Two of the students had successfully completed their Cisco certification – one to CCNA standard and the other to CCNP standard. However they still appeared to benefit from instruction based on the state model diagrams. Furthermore, student comments suggest that the diagrams allow them to link concepts that formed part of their understanding indicating that any previous studies did not provide the necessary conceptual framework. However this needs to be

further investigated. This suggests that the model may provide a learning model superior to that provided by the CNAP curriculum.

In order to evaluate this a group of students' studying the CCNA curriculum were also introduced to state model diagrams of a switch and a router throughout the semester. The diagrams were introduced during the normal CCNA lecture. At the end of the lecture students' were asked to comment on the material provided and their comments were recorded. Out of the 34 responses, 27 (79%) responded that they would like the state diagram to be used as part of the normal lecture in addition to the standard CNAP. Anonymous comments provided by the students were:

CCNA student 1: 'I think understanding the CCNA through the state diagrams is the best method I have ever seen in my life.'

CCNA student 2: 'We can look at the Cisco material at our own "leisure", so I believe to have your extra effort explained in the manner suggested is a great idea.'

CCNA student 3: 'I believe I have a greater level of understanding about switches and how they operate after today's lecture than I do about certain topics learnt / lectured from the Cisco material.'

Next it was necessary to evaluate the model from the perspective of academics from an international perspective.

By invitation the State Model Diagram was presented to academics in the Asia/Pacific region via three on-line presentations. This resulted in an invitation to present the state model as the basis of a lecture (90 minutes) on the Spanning Tree Protocol (STP) with 30 minutes allocated for questions and answers. The audience consisted of approximately thirty academics from higher education institutes (community colleges and universities) in the Asia Pacific region (Australia, China, Hong Kong, Indonesia, Korea, Malaya, New Zealand, Philippines, Singapore, Taiwan, Thailand and Vietnam.). The audience were asked to score both content and relevance of the state model as a potential teaching tool at their institution and to provide any additional comments. The content score was 4.62 out of 5 and the relevance score was 4.59 out of 5. Only four participants wrote anonymous comments as follows:

'A very good way to enhance understanding of complex problems. Makes concept learning much simpler.'

'Excellent, very informative, a new way of learning.'

'Very useful. We should look at topics of interest that are not fully explained in the CCNA and have the same type of lectures done for the next conference.'

'Excellent concept for teaching should be adopted by Cisco.'

Significantly, experienced Cisco Network Academy instructors, from a wide range of different countries, provided positive feedback for using State Model Diagrams as a pedagogical tool for teaching the Cisco curriculum.

The state model diagrams were then independently evaluated by a number of these institutions with the same results.

This university offer, in addition to offering the CCNA and CCNP courses, three University-based networking units. In these three units all instruction, laboratory exercises and all assessments are based on SMDs. The success of SMDs is such that we are now progressively using them to teach the Cisco curriculum. It should be noted that the Cisco Network Academy provides instructional material but does not mandate how the material should be taught.

CONCLUSIONS

There are advantages and disadvantages to becoming a Cisco Network Academy. Furthermore, if an institution elects to become a Cisco academy there are over 10,000 Cisco academies world wide. In this context it is difficult to achieve a unique marketing advantage. A state-wide, national and international analysis of Cisco academy network laboratories allowed us to design a new type of laboratory layout that has been independently recognized to be of international standing. In order to ameliorate the not insignificant cost these laboratories are also used for teaching non-Cisco curriculum and for research. A new method for modeling network devices, State Model Diagrams, was designed and successfully used as the pedagogical foundation of non-Cisco curriculum. Experimental work to date indicates that as a diagrammatic technique SMDs are substantially language independent. The success of all experimental work to date is such that we are now progressively teaching Cisco material using these models.

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