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Facilitating Network Technology Training in the Australian Vocational Education Sector

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Abstract

Within the Australian Further Education sector for lecturers in the IT field it is not uncommon to use vendor based curriculum. The advantages to this approach are that students can graduate not only with a national award (Certificate or Diploma) and also an internationally recognized vendor qualification. Furthermore, the larger vendors supply comprehensive course materials, resources and assessment tools all of which have been extensively tested. In effect lecturers do not have to write their own course materials. Whilst it is recognized that lecturers may well facilitate student learning the quality of the educational outcomes is highly dependent on the quality of the vendor based materials. In the case of the Cisco Network Academy Program (CNAP) course materials did not provide a consistent diagrammatic representation of networking devices and protocols. Educational theory strongly suggests that such a model is the basis of quality teaching and learning. In this study student learning was evaluated using the State Model Diagram (SMD) method and the interpreted using the SOLO taxonomy. The results clearly demonstrate that there are considerable advantages to using the SMD method.

Keywords: state model diagrams, Cisco Network Academy Program, network technology education

1. Introduction

1.1 Australian education sector

Within Australia there are three education sectors – Schools, Vocational Education & Training (VET) (aka Further Education) and Higher Education (Universities). VET sector courses typically range from Certificate (II, III and IV) to Diploma level. Students enrolling in the VET sector typically have a strong preference for courses requiring less theory and significantly more practical hands-on workshops. The VET sector is industry driven at a national level and hence based on training packages that are developed and maintained by industry specific Industry Skills Councils (ISCs) with defined development and endorsement processes. Within the IT discipline it is not uncommon to base these national training packages on vendor based courses such as Microsoft, Red Hat, Cisco etc. The larger vendor based courses provide extensive course materials that are also the basis of professional training courses globally. At the institution analyzed for this paper the Certificate III was designed to incorporate the Cisco Discovery curriculum and the Certificate IV incorporates the Cisco Certified Network Associate (CCNA) curriculum. Hence at the successful conclusion of their course students can graduate not only with a VET award but also an internationally recognized, industry standard award. The prerequisite for entry to the Certificate IV is successful completion of the Certificate III. The quality of vendor based VET qualification is therefore largely dependent on the quality of the vendor based curriculum.

1.2 Cisco Discovery Curriculum

Since its inception in 1997 the Cisco Network Academy has expanded to 9,000 institutions ranging from schools to universities in over 170 countries. The Cisco Network Academy Program (CNAP) consists of a wide range of globally recognized technology education courses and is considered an exemplar of best practices in blended and online learning. It should be noted that only Cisco qualified instructors are allowed to teach on Cisco Academy courses thereby ensuring educational quality on a global basis. The CNAP Discovery curriculum consists of a wide range of resources that include: Instructor reference guide; Learning with Cisco Network Academy guide;

power point slides; Packet Tracer simulator; Packet Tracer instructional guide; on-line study material; assessments etc. The Cisco Certified Network Associate (CCNA) is at a higher educational standard but similarly includes extensive course materials. The course materials are used to support self-directed learning that is facilitated by instructor support.

1.3 Higher Order Learning

The quality of learning can be evaluated using a cognitive taxonomy such as Bloom (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956), (Akamatsu, 2007). The Bloom taxonomy has both its advocates and its critics. An alternative, but equally valid approach to classifying learning outcomes is the Structure of Observed Learning Outcomes (SOLO) taxonomy with four category definitions (Biggs & Collis, 1989) – uni-structural, multi-structural; relational and extended abstract. Uni-structural and multi-structural are low order learning outcomes allied to rote learning. The relational and extended abstract categories represent deep, high order learning outcomes. Higher order learning outcomes can be related to the cognitive science concept of a schema. A schema is mental construct and schemas are organized into relational networks called schemata (Rumelhart, 1980). Deep understanding is defined by schemata in long term memory. Leaning consist of building these mental constructs. Ideally course material will facilitate higher order learning outcomes by identifying relational patterns and explicitly represent them as the basis of course material. How material is taught may either handicap or facilitate learning. In the Cisco Discovery course material the function of a switch is described using a diagram and associated text (Figure 1). Similarly the function of a router is described using a diagram and associated text (Figure 2). Whilst both diagrams are technical correct they are incomplete in that they fail to explicitly identify the relationships between the key learning concepts. The interfaces on the switch are not identified; neither are the PC hardware addresses associated with PCs; hence the reader is left to create their own cognitive model which could be incorrect. Furthermore the diagram in figure 1 does not show that a switch is an OSI layer 2 device. In the router diagram (figure 2) the interfaces are defined but the MAC addresses of the PCs are again not defined. This is problematic because if students are not taught using a coherent relational knowledge model they are highly likely to develop their own cognitive model that is incomplete, inconsistent and incorrect. According to Von Glasserfield teachers need adequate models as the basis of instruction (von Glasersfeld, 1982).

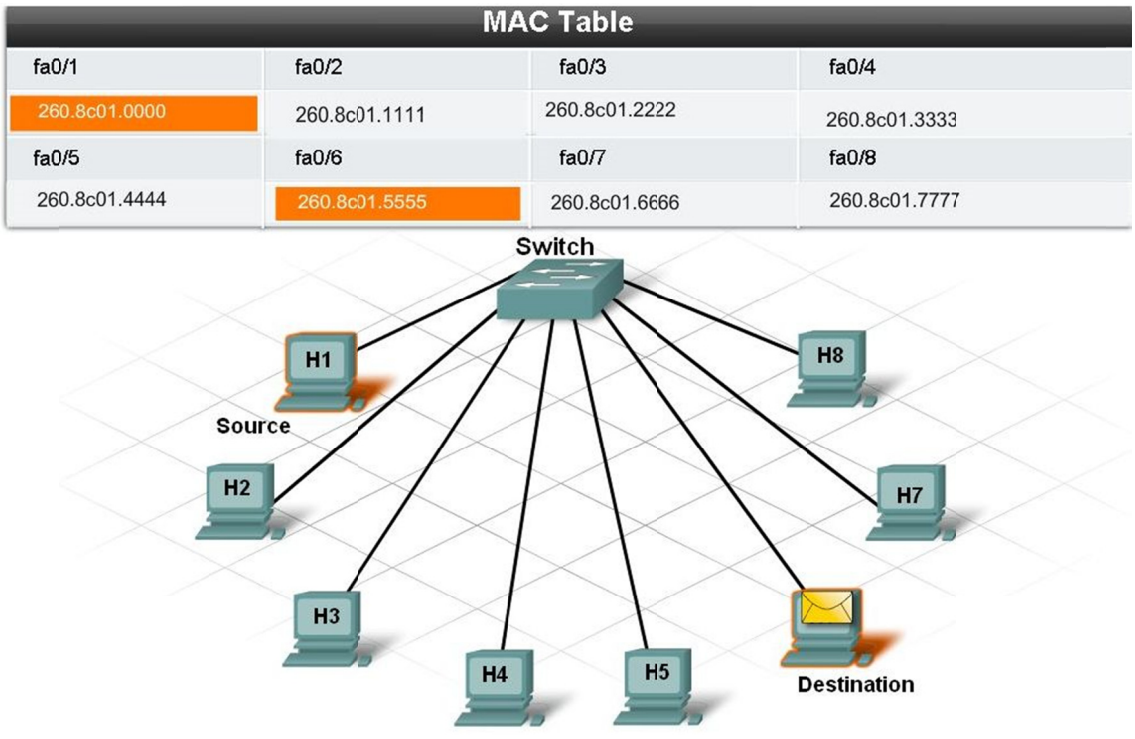

Figure 1. Cisco Discovery diagram of a switch

Describe how the router keeps tract of multiple networks using routing and ARP tables

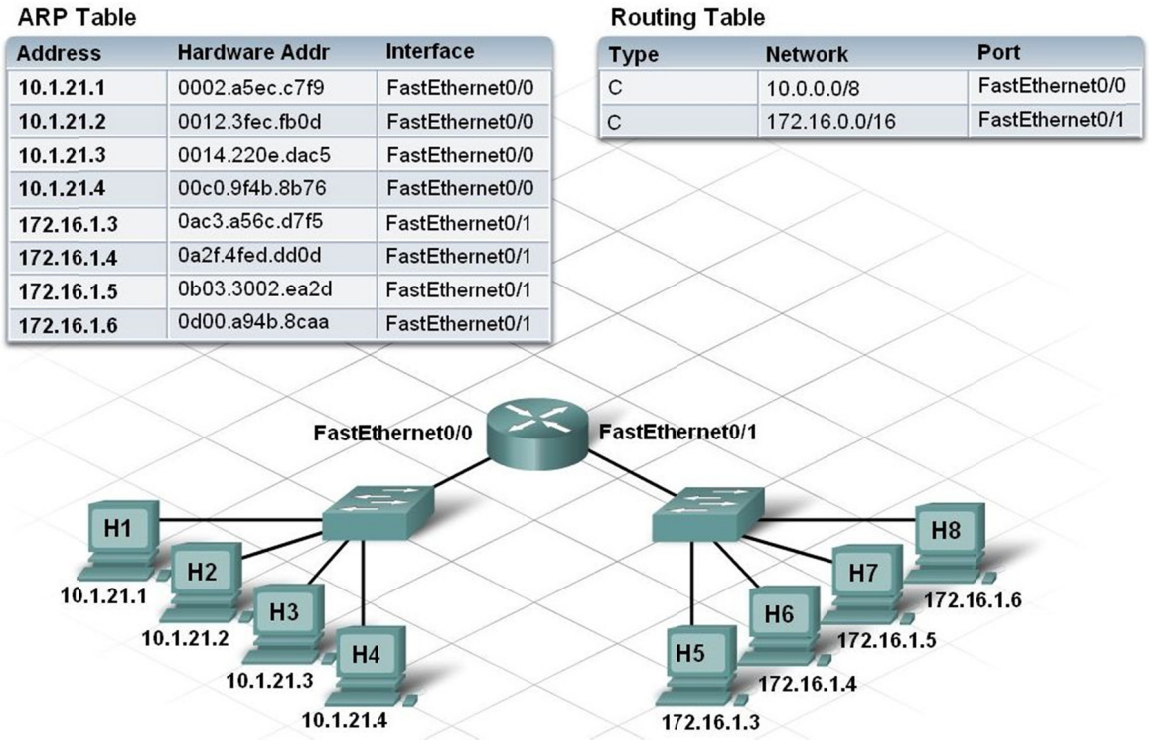

Figure 2. Cisco Discovery diagram of a router

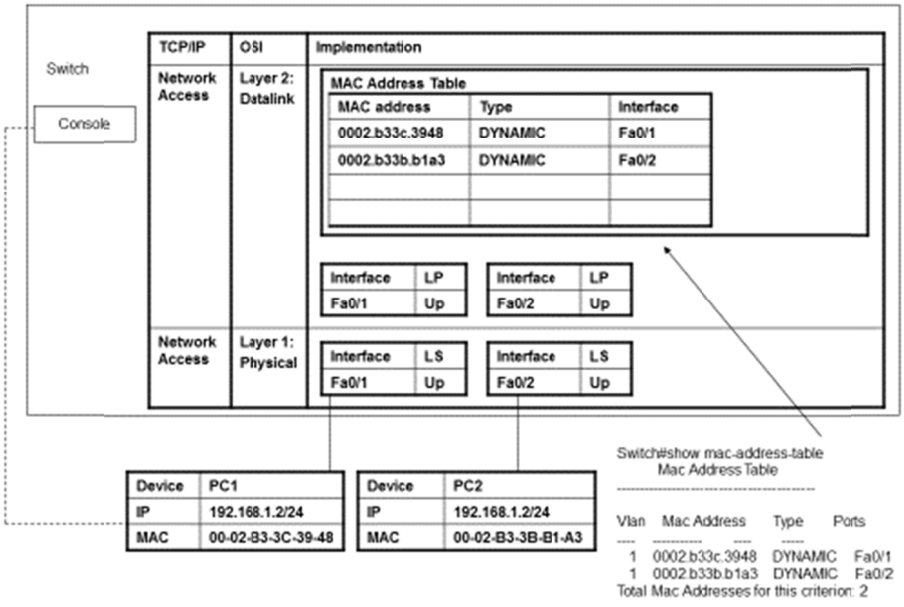

Figure 3. State Model Diagram of a Switch with address learning

1.4 State Model Diagrams

Maj proposed a relational, diagrammatic model called State Model Diagrams (SMDs) (Maj & Kohli, 2004). Significantly the SMD method explicitly defines relational knowledge all in a single diagram. A switch

represented by the SMD method explicitly shows the two interface protocols – Line Status (LS) and Line Protocol (LP) contextualized according to the OSI layers (Figure 3). This diagram also explicitly shows that the MAC address table is an OSI layer 2 implementation that maps interfaces to MAC addresses dynamically. This single diagram also shows two connected PCs with the associated MAC addresses. The IP addresses of the PCs are included for the purpose of testing PING connectivity. From this diagram it is possible to see that each PC MAC address is associated with an interface mapped by the MAC address table. This diagram can be used in the laboratory when using a real switch and PCs. The switch command switch#show mac-address-table output in this experiment can be used to populate an empty SMD. In effect a single SMD can be used to represent the main data extracted from Command Line Interface (CLI) and link this information to device operation. A network diagrammatically modeled using SMDs can directly link the concrete (the devices and connectors) to the abstract (protocols etc.) SMDs are a diagrammatic means of teaching as opposed to the sequential text based CLI. It is possible using SMDs to demonstrate the relationships and interactions between network devices and their protocols. This is important because higher order learning requires students to think not only about multiple things but also how those objects interrelate. A single SMD can represent the output from multiple CLI commands and hence show concurrent interactions between different devices and associated protocols. In effect SMDs are designed to assist students make the transition to deeper learning e.g. from multi-structural to relational. This single diagram of a switch can be used to show dynamic address learning by moving the two PCs to different interfaces (Figure 4). When student learning has advanced it is then possible to reduce the diagram foot print by removing the OSI layer mapping and the console connection. This single diagram can be used to teach: address learning; flooding; forwarding and filtering to create virtual circuits; broadcast and collision domains; memory buffers and VLANs. In effect therefore new knowledge is contextualized which also reinforces earlier learning. The initial State Model Diagram of a router would include a mapping of the OSI model. To reduce the foot print of the diagram this can be removed but is should be noted that each device contains three levels representative of the OSI layers (Figure 5). This allows a single diagram to contain a fully populated router and two PCs. This single SMD router representation explicitly shows the relationship between: MAC addresses; IP addresses and the associated interfaces; ARP table and functionality; gateway IP and the routing table. To reinforce understanding students can be provided with a topology map (devices, IP addresses only) which must be built in the laboratory. When the network has been constructed students can extract from the router configuration details and hence populate a blank SMD.

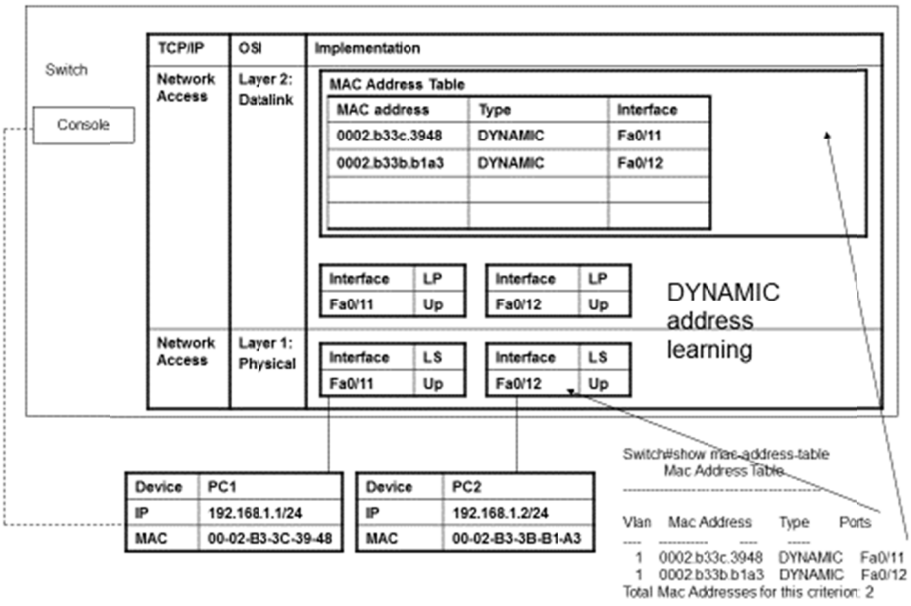

Figure 4. State Model Diagram of a Switch with PCs moved to different interfaces

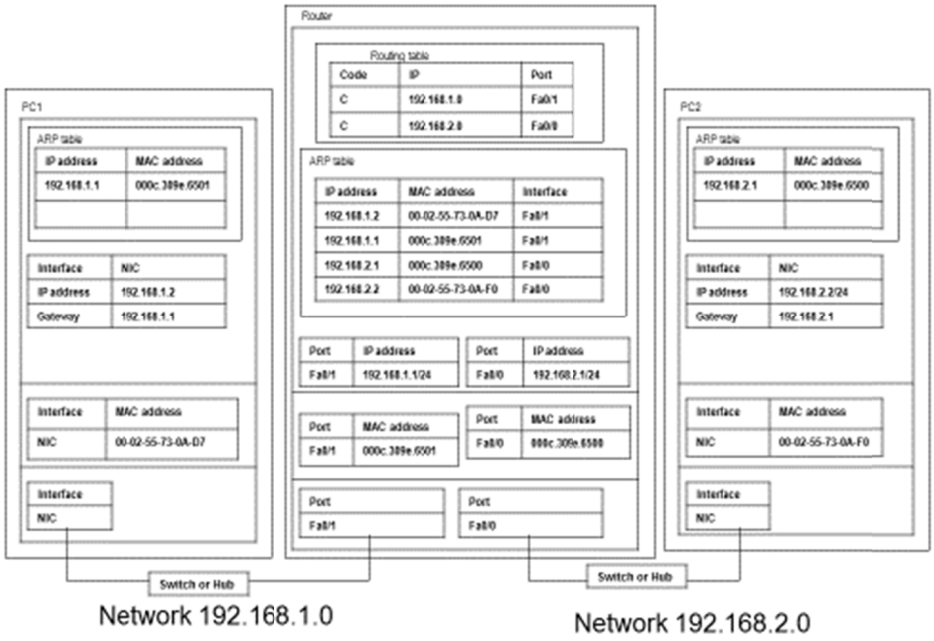

Figure 5. State Model Diagram of a single router and two PCs

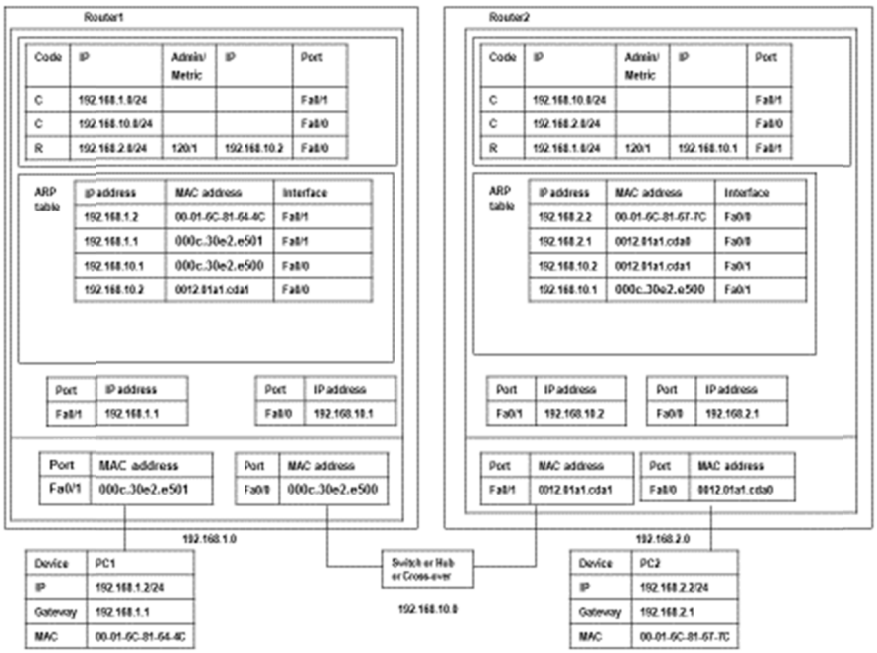

Figure 6. State Model Diagram of a two routers

2. Method

2.1 Participating Population

The course content for the Cisco Network Discovery curriculum was analyzed to determine the main educational concepts. These were determined to be:

- Binary representation of data
- PC architecture and Operating Systems

- Communication protocol concepts
- Cabling and connectors
- Ethernet LAN
- Switching
- Routing
- IP addressing
- NAT, DHCP, DNS
- TCP and UDP
- Testing

Course material was written based entirely using State Model Diagrams (SMDs). Three groups of students on three different courses were analyzed namely;

Group 1 - Certificate III students were taught using only SMD based material instead of the Cisco Discovery material. All instruction, workshops and assessments were based on SMD principles. At the end of the course of instruction these students were given an overview of the Cisco Discovery curriculum.

Group 2 - Certificate III students taught using the Cisco Certified Network Associate (CCNA) curriculum. These students were given an overview of State Model Diagrams

Group 3 - Certificate IV students were taught entirely based on the Cisco CCNA course material. These students were given an overview of State Model Diagrams

2.2 Method

Volunteers from these three groups completed the same questionnaire based on a Likert scale (Strongly Agree; Agree; Neutral; Disagree; Strongly Disagree). It was a requirement that volunteers also participate in an interview in order to elucidate student perceptions and clarify any ambiguities. All comments were recorded. Prior to the interview students from group 2 and 3 were given an overview of the SMD method and answered any questions regarding its use as an educational tool. Given the need to explain the SMD method and possibly an extensive interview there were relatively few volunteers. However for these few volunteers the objective was to obtain as rich a perceptual perspective as possible.

3. Results

Question 1**:** State Model Diagrams (SMDs) can assist in understanding general networking concepts

Group 1 responses

SA	A	N	D	SD	Null
2	1				

Group 2 responses

SA	A	N	D	SD	Null
2					

Group 3 responses

SA	A	N	D	SD	Null
4					

Question 2**:** State Model Diagrams can help to explain how each of the (networking) OSI layers interact.

Group 1 responses

SA	A	N	D	SD	Null
1	2				

Group 2 responses

SA	A	N	D	SD	Null
2					

Group 3 responses

SA	A	N	D	SD	Null
2	2				

Question 3: State Model Diagrams are useful to help control the complexity of networking.

Group 1 responses

SA	A	N	D	SD	Null
1	2				

Group 2 responses

SA	A	N	D	SD	Null
1	1				

Group 3 responses

SA	A	N	D	SD	Null
	4				

Question 4**:** State Model Diagrams control complexity help show how network devices communicate with each other.

Group 1 responses

SA	A	N	D	SD	Null
3					

Group 2 responses

SA	A	N	D	SD	Null
1	1				

Group 3 responses

SA	A	N	D	SD	Null
	4				

Question 5**:** State Model Diagrams could be used with other network protocols (OSPF, EIGRP etc.).

Group 1 responses

SA	A	N	D	SD	Null
	1				2

Group 2 responses

SA	A	N	D	SD	Null
	1	1			

Group 3 responses

SA	A	N	D	SD	Null
	1	1			2

Question 6**:** State Model Diagrams would be useful for teaching networking to students.

Group 1 responses

SA	A	N	D	SD	Null
3					

Group 2 responses

SA	A	N	D	SD	Null
2					

Group 3 responses

SA	A	N	D	SD	Null
3	1				

Question 7**:** State Model Diagrams help in practical applications of routing and switching.

Group 1 responses

SA	A	N	D	SD	Null
1	2				

Group 2 responses

SA	A	N	D	SD	Null
1	1				

Student comments

Group 3 responses

SA	A	N	D	SD	Null
1	3				

Question 8**:** State Model Diagram based teaching can help build your interest and/or confidence in networking.

Group 1 responses

SA	A	N	D	SD	Null
1	2				

Group 2 responses

SA	A	N	D	SD	Null
1	1				

Group 3 responses

SA	A	N	D	SD	Null
1	3				

Question 9: If given a choice I would prefer to be taught using SMD based course materials in preference to Cisco Discovery course material.

Group 1 responses

SA	A	N	D	SD	Null
2	1				

Group 2 responses

SA	A	N	D	SD	Null
2					

Group 3 responses

SA	A	N	D	SD	Null
1	3				

Question 10: If I was taught using the SMD method I would learn more, faster and better.

Group 1 responses

SA	A	N	D	SD	Null
1	2				

Group 2 responses

SA	A	N	D	SD	Null
2					

Group 3 responses

SA	A	N	D	SD	Null
	4				

Question 11: If I was taught using the SMD method I would better understand how network devices work.

Group 1 responses

SA	A	N	D	SD	Null
1	2				

Group 2 responses

SA	A	N	D	SD	Null
2					

Group 3 responses

SA	A	N	D	SD	Null
	3	1			

Question 12: Did you find the Cisco Discovery content was clear\concise in explaining networking.

Group 1 responses

SA	A	N	D	SD	Null
		1	2		

Group 2 responses

SA	A	N	D	SD	Null
		1		1	

Group 3 responses

SA	A	N	D	SD	Null
		1	2	1	

Question 13: The Cisco Discovery content helped in understanding networking and protocols.

Group 1 responses

SA	A	N	D	SD	Null
		2	1		

Group 2 responses

SA	A	N	D	SD	Null
		1		1	

Group 3 responses

SA	A	N	D	SD	Null
1	1	1	1		

Student comments were as follows:

Group 1

SMD's are more fleshed out than Discovery 1 content.

Group 2

I ran off copies of (SMD) material and actually did use it in my practical applications in Cert III.

The Cisco Discovery 1 content was quiet clear in the description of how systems work but not as effective as the SMD in my learning. In understanding concepts the SMD was much more beneficial to my way of learning and understanding.

The style of delivery and content (of Discovery 1) was substandard compared to SMD method.

That was first time I had been exposed to that method of learning (SMD) and I find it hugely beneficial in my units in university studies at the moment. I apply the same concept when I am doing my mind mapping to understand concepts in the course I am in at the moment. Definitely a method I will be taking with me to carry on my learning throughout my university degree.

Group 3

I put down strongly agree (SMD can assist in understanding general networking principles) because I am more of a visual person. It just lays things out a bit more precisely instead of imaging my own thing. Having a standard to stick to is really helpful.

(SMDs) make things easier for visual thinkers and hence learn easier and better.

You start off slowly (with SMD method) and continue using the same method. Cisco constantly uses different types of diagrams.

I prefer the SMD method because I found the Cisco material is dragged out.

I learn quicker with the (SMD) visual aids.

I found some parts of the Cisco material confusing.

The Cisco material is very thorough.

SMDs help paint a broader picture of how general networking concepts come together. SMDs do a very good job of it.

You can clearly see in SMD how the layers 3, 2 and 1interact with MAC addresses, IP addresses and interfaces. Yeah, it works very well.

You can clearly see the SMD shows not just each network device itself but what part each plays and how it communicates with other devices in the network.

The SMD is very modular and flexible. You keep the base model.

For some students there might be an initial learning curve (with SMD method) that might frighten them but if they overcome that initial hurdle it will definitely make things easier down the road.

Because SMD controls complexity and it's got a broad picture and helps understand fundamentals I think if students learn that, I do not know about their interest, but it will definitely build their confidence because they know what they are doing.

I think the CCNA has some good quality teaching in it but the SMD is much more clear and concise than the CCNA material.

The SMD gets to the chase of what is important in networking. I think a lot of the Cisco material is useful but a lot of it is not quite as useful so to speak.

With the broad picture you get with State Model Diagram you can clearly see how each of the devices is interconnected with one another.

The CCNA material is useful but a lot of their explanations they have isn't the same, it's not got a standard that follows. So some examples they use are not the same as others while State Model Diagram is consistent in the way that it explains networking.

It (CCNA) has helped me in understanding. It is definitely good as a starting point. Maybe the Cisco material can work in conjunction with State Model Diagrams having the Cisco material as a starting point and then once the students are comfortable they could use State Model Diagrams to enhance their learning.

Group one students were taught networking principles and concepts using the State Model Diagram method but towards the conclusion of their studies exposed to the equivalent Cisco material. Excluding question 5 on topics these students have no knowledge, 100% of students either Strongly Agree or Agree regarding the benefits of the SMD method. Regarding the Cisco material 100% were either Neutral or Disagree regarding its effectiveness. Group two students were at the same Certificate III standard but all learning was based on the Cisco material. At the start of the interview these students were given a brief overview of the SMD method. Despite the brief explanation 100% of these students either Strongly Agree or Agree regarding the benefits of the SMD method. Significantly this cohort was either Neutral or Strongly Disagree regarding the quality of the Cisco material. Group three students were at the higher Certificate IV level and their learning was entirely based on Cisco material. Again this cohort of students was given a brief introduction to the SMD method at the start of the interviews. Excluding question 5, 100% of this cohort responded with either Strongly Agree or Agree regarding the value of the SMD method. This group of students was at a more advanced academic level and this was reflected in the extensive comments provided. The comments are almost entirely positive regarding the effectiveness of using the SMD method in preference to the Cisco course materials.

4. Discussion

Clearly for this study there is only a relatively small sample size and can best be seen as a pilot study. Despite this there is overwhelming support and agreement that the SMD method has considerable advantages in particular that the same model is used for all networking devices and protocols. This approach allows students of scaffold their leaning in a more efficient manner. As such, in this study, it is a preferred method for learning networking principles and concepts. However further and more extensive work is needed.

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