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Balancing Theoretical and Practical Goals in the Delivery of a University-Level Data Communications Program

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EXECUTIVE SUMMARY

This case examines the experience of introducing the Cisco Networking Academy Program as part of two data communications courses taught in the School of Business and Economics at the University of Auckland. This case discusses the advantages and disadvantages encountered in the administration and delivery of the combined (traditional content plus the Cisco-based content) material. The case also analyses the impact of the program on the learning outcomes and objectives of the existing courses. The feedback presented was obtained informally through conversations with students and formally by using end-of-semester surveys and by reviewing students' assignments and tests. The case describes how the program combined traditional "sage on the stage" lectures plus hands-on lab experiments as part of the educational experience. The availability of on-line curricula and testing is also considered as an important element in the learning process.

BACKGROUND

The University of Auckland was established in 1883 and it is New Zealand's largest research university with more than 28,000 students. It offers a comprehensive range of study programs attracting postgraduate and undergraduate students from over 50 countries. In 2000 the university was New Zealand's top-ranked institution in *Asiaweek* magazine's annual survey of Asian and Australian universities (*Bachelor of Commerce—The Undergraduate Handbook*, 2002). The university has four campuses with seven faculties representing a number of disciplines: Architecture, Property, Planning and Fine Arts; Arts, Education and Music; Business and Economics (also known as the University of Auckland School of Business); Engineering; Law; Medical and Health Sciences; and Science. More than 4,000 students are enrolled for postgraduate studies (nondoctoral) and around 900 for doctorates. Some departments are associated with more than one faculty and various research centres cross disciplinary boundaries (Slattery, 2002).

The university's governing body is the Council, a mixture of elected staff, students and graduates, and outside appointees. The vice-chancellor, the university's chief academic and administrative officer, is also a member of Council. On academic matters the Council is bound to consult the Senate, which the vice-chancellor chairs. The Senate includes all the full professors, some nonprofessorial staff and student representatives. Each faculty is a subcommittee of the Senate and is headed by a dean who is responsible for overseeing the academic and research activities of individual departments and, in coordination with Registry and Senate committees, manages aspects related with staff appointments, research funding, time-tabling, etc. The Registry performs central administration, and it is divided into Information Technology Systems and Services (ITSS), Finance, Human Resources, Student Administration, and Property Services sections (Slattery, 2002). Financial information (university revenues and expenditures) for the year 2000 is included in Appendix 1.

The School of Business has over 200 academic staff and seven departments: Accounting and Finance, Commercial Law, Economics, International Business, Management and Employment Relations, Management Science and Information Systems, and Marketing. The school offers more than 350 courses in 15 major fields of study, and there are approximately 6,000 students currently enrolled in the faculty programs (*Bachelor of Commerce—The Undergraduate Handbook*, 2002).

SETTING THE STAGE

The courses studied in this case study, Data Communications and Advanced Data Communications, are taught on the second and third years of a three-year bachelor of commerce (BCom) degree in information systems. Students enrolled for the BCom degree have to follow a program that is equivalent to three full-time years and pass courses with a total value of at least 42 points. A typical one-semester course is worth two points. Of the 42 points required for this degree, a student must pass at least 22 points in course above Year I, and s/he must complete one or more majors, including at least six points in Year III in each major. A normal course load is comprised of 14 points per year. The maximum load per semester is nine points.

The data communications courses can also be taken by BSc (computer science) and BTech (information technology) students; however it is important to note here that the courses are optional and are not part of the mandatory core of any major approved for BCom, BSc or BTech students.

The second-year course typically has enrolments of approximately 360 students roughly distributed in three classes of about 120 students each. Around 120 students take the third-year course. In the past the material has been delivered by lecturing three hours per week (12 weeks per semester) and by making available to students one optional tutorial hour per week during eight weeks. The coursework assessment consisted of two tests, two research assignments, a laboratory assignment (running CACI's Comnet III networking simulation software), and a group design project. For the design project students formed self-selected groups of four and produce a number of deliverables with staggered hand-in dates distributed throughout the semester. An outline of the contents of the course is found in Appendix 2.

The third-year course had enrolments of around 130 students in one stream during the second semester of each year. The course dealt with detailed descriptions of the seven layers of the OSI reference model, concentrating on the primitives used among the different layers and studying the object-oriented aspects of the standards. Students were formally introduced to the syntax notation used with this type of modelling, and the applications of these techniques were discussed. The coursework assessment consisted of two tests, two assignments, and an Abstract Syntax Notation One (ASN.1) project. An outline of the contents of the course is included in Appendix 3.

Anecdotal feedback from students had clearly identified that they found this course to be highly theoretical. Unlike the second-year course, there was no lab component or group-based assignments.

CASE DESCRIPTION

In late 1999 a casual contact with the Cisco New Zealand country manager led the department of Management Science and Information Systems (MSIS) to consider the possibility of becoming a regional academy and of introducing the Cisco Networking Academy Program as part of the data communication courses. The networking academy is a Web-based program with curricula accessed through a Web browser and comprises significant practical experience carried out within a lab environment. On completion of the training, the students will be prepared to sit the Cisco Certified Networking Associate (CCNA) and Cisco Certified Networking Professional (CCNP) accreditation tests at any of a number of independent testing centres (Cisco Systems, 2000).

The Cisco Networking Academy Program was launched in the United States in October 1997 and in the Asia Pacific region in September 1998. Today, there are more than 8,000 academies operating in 140 countries worldwide and some 270,000 students enrolled (Cisco Systems, 2002). The program supports instructors' needs by providing lab equipment, software (including automated grade books and course administration tools), lesson plans, technical support and access to a global community of fellow instructors. Students benefit from the use of an on-line curriculum that can be accessed (after proper authentication) from any browser-enabled device and from assessment facilities that provide timely learning feedback.

The Cisco program includes instruction in the following areas: safety, networking, network terminology and protocols, LANs, WANs, the OSI model, cabling, cabling tools, routers, router programming, network topologies, IP addressing, virtual LANs, network switching, network troubleshooting and network standards. Particular emphasis is given to the use of problem-solving techniques and design methodologies to solve networking problems. The course includes a threaded case study used to illustrate the most important issues associated with a large-scale networking design project.

Adapting the Cisco Networking Academy Program

The Networking Academy Program was aimed at high-school pupils studying the last two years of their secondary studies or/and to first- and second-year tertiary students. In many cases the curriculum is delivered exactly as suggested by Cisco without any changes or enhancements. The MSIS data communication courses have traditionally covered additional material, and several aspects of the subject area are treated at a higher level of detail. To preserve the integrity of the courses the department decided to integrate the Cisco curriculum as an additional practical component without sacrificing or reducing the core contents of the courses. This decision resulted in a "localisation" of the Networking Academy Program to fit the institution's goals. The main consequences of that decision are:

- The program is not delivered exactly as prescribed by Cisco,
- Some sections of the curriculum are not covered during the lectures or tutorials and students are advised to self-study that material, and
- Key lab activities are performed but some labs are not delivered.

The 280-hour, four-semester curriculum has been combined with three of the MSIS courses as follows:

Data Communications (second-year): three lecture hours and one tutorial hour per week (during 12 weeks). Nine labs (one hour each). Includes Semester 1 of the Cisco Networking Academy Program.

Advanced Data Communications (third-year): three lecture hours and one tutorial hour per week (during 12 weeks). 10 labs (one hour each). Includes Semester 2 of the Cisco Networking Academy Program.

Computer Networks (third-year): three lecture hours and one tutorial hour per week (during 12 weeks). 10 labs (one hour each). Includes Semesters 3 and 4 of the Cisco Networking Academy Program.

Advantages of the Program

The arrangement discussed in the previous section aims at achieving a combination of the "best of both worlds" by maintaining the core contents of the university courses while complementing them with the Web-based Cisco Networking Academy Program curriculum and the lab assignments. The curriculum has now been changed to accommodate different learning styles by employing multiple media to deliver content—text, audio, extensive graphics and movies. The learning takes place in three main steps:

1) Presentation and teaching of concepts,
2) Demonstration, clarification of issues and linking of concepts to a particular current task (use of examples and analogies), and
3) Hands-on lab experiments.

The students have access to the on-line material at any time and from any place; however the on-line tests and exams are conducted in a controlled environment.

Computer-aided instruction is used as one of a combination of teaching techniques (Alessi & Trollip, 1991), and student learning is improved through the adherence to a set of "best practices," which are contained in a document of the Cisco Networking Academy Program instructor support resources. Best practices are a broad set of activities that are intended to assist student learning. Examples of best practices include challenges, design activities, graphical organizers, group work, journals, kinesthetic activities, lab exams, mini-lectures, on-line study, oral exams, portfolios, presentations, rubrics, study guides, trouble-shooting and Web research. To ensure that improved learning is taking place, instructor guidelines are presented that facilitate the matching of one or more best practices with the hierarchical framework for multiple levels of thinking associated with Bloom's taxonomy

(1956). Bloom's taxonomy includes six levels of thinking starting from knowledge, working their way up through comprehension, application, analysis and synthesis, and ending with evaluation. Since the best practices provide a variety of opportunities to learn, the question becomes what is the best mix of activities, given current subject matter, goals (both organizational and student), and available resources, throughout the delivery of the course. It is the alignment of appropriate best practices with subject matter that is invaluable in ensuring a rewarding learning experience for students.

The network design project that was usually included as part of the second-year course has been postponed to the third-year and included in the last course of the program as a threaded case study. The objective of this change is to prepare the students for a complete year before they attempt the group project. Many of the concepts introduced and practiced during that year assist them in producing better results. In the past, students produced group project reports that were good, sometimes excellent, given the limited exposure to the subject area. With the addition of the Cisco Networking Academy Program components, the students were able to produce more professional results using their more detailed knowledge and applying a number of procedures, skills and techniques for the analysis, design, implementation and presentation of their case studies. This task provides the perfect example of a "synthesis" activity as discussed in Bloom's taxonomy. Students combine the theoretical knowledge acquired and the practical skills learned in the "putting together of elements and parts so as to form a whole" (Bloom, 1956).

The main weakness of the previous reports from group projects lay in the fact that many of the solutions proposed by the students were missing key components (for example: lack of adequate interfaces in the routers proposed or lack of security) or simply wouldn't have worked due to compatibility problems. These omissions were easier to spot when producing their case studies because by then students have been exposed to detailed information and practice (in the labs) about how to properly configure and design LANs and WANs. Their understanding of user and business requirements and how to integrate them into the design was also superior; even their writing and presentation skills (as last-semester students) have improved.

The synergy achieved by using the labs to provide hands-on learning and skill-set development as a complement to the theory delivered during the lecture hours was invaluable. Lecturers were able to maintain student interest by providing immediate links to lab activities. An otherwise dry and complicated explanation about link-state routing protocols, for instance, can be enlightened by hands-on tasks where students "see" the protocol operating and the routers exchanging information about the state of the links between them. The labs provided opportunities for students to engage their network troubleshooting skills and were an important instrument for the delivery of the higher- order educational outputs of critical-thinking and problem-solving abilities. This synergy produced many "Aha!" moments, whereby suddenly an abstract concept is finally grasped. Needless to say these moments were very satisfying for both learners and instructors.

Disadvantages of the Combined Program

The major disadvantage of the combined (Cisco Networking Academy Program plus the university's) program was the additional resources requirements. Lab facilities are essential, including room allocations, time-tabling for the different courses and streams, hardware, software and Internet connections. Additional staff was also needed to teach and supervise the lab sessions. It is not unusual for a typical class (three lecture hours per week) to require more than six one-hour lab sessions per week. This additional load cannot simply be added to the teaching workload of the course lecturer. Additionally, extra course coordination tasks were necessary; for example, the Cisco assessment system needs an administrator/user to add students to the system, activate chapter tests and exams, print certificates, etc.

Students' Evaluations

The Centre for Professional Development at the University of Auckland uses the Students' Evaluation of Educational Quality, or SEEQ, which is a well-tested instrument that generates a profile of teaching performance. It provides comprehensive feedback from students to support improvement related to each of a number of factors, and it has been shown to improve the quality of teaching when feedback is combined with consultation.

Students were asked to respond to a number of questions using a rating scale. A five-point Likert scale was used from *strongly agree* to *strongly disagree*, with a neutral response category as well. For enhanced face validity, the numbers are converted as follows: 1=0, 2=2.5, 3=5, 4=7.5, and 5=10. This gives a "mark out of 10." The SEEQ collects student perceptions of an individual lecturer's performance on 35 items across nine scales, data concerning difficulty and pace of the course, and qualitative data for feedback to the lecturer. Additionally there are two questions about overall ratings of the course and of the lecturer.

Tables 1 and 2 show a comparison of SEEQ results between the data communication courses. The six scales selected are course-related. The Group Interaction scale was not measured in 2001 for the Data Communications course and is therefore not shown in the first table. Lecturer-specific scales have been eliminated from this comparison. The 2000 offerings did not include the Cisco curriculum as the practical component of the courses.

All categories show improvements for 2001 and all categories are now located above faculty averages for the same year. Additional course feedback was also obtained by using the Course Feedback questionnaires included in the Cisco Networking Academy Program.

Table 1. SEEQ Evaluation Results for the Data Communications Course

Data Communications	2000	2001	Improvement	Faculty Mean 2001
Learning and Academic Value	6.05	7.06	16.7%	6.79
Organization and Clarity	5.99	6.75	12.7%	6.44
Breadth of coverage	6.63	7.30	10.1%	6.34
Assignments and Readings	5.51	6.79	23.2%	6.45
Overall Rating	5.97	7.21	20.8%	7.00

Table 2. SEEQ Evaluation Results for the Advanced Data Communications Course

Advanced Data Communications	2000	2001	Improvement	Faculty Mean 2001
Learning and Academic Value	5.74	7.46	30.0%	6.38
Organization and Clarity	4.74	7.33	54.6%	6.30
Group Interaction	6.14	7.52	22.5%	6.36
Breadth of coverage	6.24	7.30	17.0%	6.37
Assignments and Readings	5.02	6.79	35.3%	6.53
Overall Rating	4.87	7.83	60.8%	6.14

Some categories were not covered in the SEEQ instrument and are of special interest to this case study. Those results (converted to a 10-point scale to facilitate comparisons) for 2001 are shown in Tables 3 and 4.

CURRENT CHALLENGES FACING THE ORGANIZATION

The list of advantages for the delivery of a data communications course that contains the prevailing academic rigour of similar undergraduate courses delivered in the department, along with an emphasis of the acquirement of vocational hands-on skills that the Cisco Networking Academy Program desires, was sufficient to ensure the continuation of the program in its new form. It does however present the university with a number of challenges.

Implementation Issues

A set of challenges to the organization exists surrounding the centralized management of computing resources within the university. This function is provided by ITSS, which has been mentioned earlier and is a division of the university's central administration body, the Registry. Part of the Cisco Networking Academy Program requires students to become familiar with the operating system to the extent that they can configure a workstation for the proper settings in order to function on a network. This requires access and privileges that are not typically granted to either undergraduate or postgraduate students. A second problem relates to the requirement for the laboratories of approved Cisco training academies to provide a continuous and direct Internet connection. Students generally access the Internet as a controlled resource, whereupon they must pay funds into an account and the funds are deducted based on data volume accessed from the Internet. As the decision was made to allow all workstations in the lab unrestricted access to the Internet, it was necessary to manage access and usage of the lab. A final problem occurs based on the nature of some of the network equipment used in the Cisco Networking Academy Program labs. Specifically many of the labs from the second data communications course present tasks and activities that are derived from a simulated wide-area-network topology and this is facilitated through

Table 3. Networking Academy Evaluation for the Data Communications Course

Item	Result
The activities and labs helped me achieve the stated course objectives	7.96
The assessment tools helped me evaluate my knowledge of the lesson	7.82
Overall, the course materials were of high quality	8.18
The classroom and laboratory provided a comfortable learning environment	7.60

Table 4. Networking Academy Evaluation for the Advanced Data Communications Course

Item	Result
The activities and labs helped me achieve the stated course objectives	7.98
The assessment tools helped me evaluate my knowledge of the lesson	7.62
Overall, the course materials were of high quality	8.28
The classroom and laboratory provided a comfortable learning environment	7.92

the interconnection of a number of routers. ITSS was clear in specifying that at no time could data from this network topology be allowed entry back onto the university network. This presents the problem of having a single lab that at times requires unrestricted access to the Internet through the university backbone and at other times needs to be isolated completely from the university backbone.

Another challenge is provided by parallel assessment information systems that result from the integration of the Cisco Networking Academy Program. Enrolment and assessment of university students are through a computerised facility with different levels of access for staff and students. Students can view the results of their assessment components as the course progresses. Enrolment and assessment of the Networking Academy Program are through the worldwide Cisco Network Academy Management System (CNAMS). Students see the immediate results from the standardized multi-choice testing system of the Cisco Networking Academy Program. As the Networking Academy Program contributes only 30% of the assessment to the course, it is possible for students to pass the Networking Academy Program and yet fail the total assessment requirement for the undergraduate data communications course. If a student fails a course, they might choose to sit it again in a subsequent semester. When the student resits the course, they are expected to complete the course as if it was their first attempt, and they are expected to repeat the assessment components as they are specified. A solution was required to address the fact that CNAMS does not allow a successful student to repeat stages.

An additional implementation issue deals with the way the Networking Academy Program in its original form becomes progressively more skills based. It is typical within the university to maintain a structure of three lecture hours and one tutorial hour per week per course. The problem of increased practical content delivery in the form of extra labs is representative of providing flexible components and units of content delivery. Examples of components include lectures, tutorials, laboratories and exams, and the unit for these is represented as time, which is often constrained to work with one-hour blocks.

Educational Issues

Innovative approaches are required to balance the teaching and learning goals of the respective organizations. For the university (University of Auckland, 2002), selected strategies of teaching and learning (from the complete list) include:

- "providing a student-focussed teaching and learning environment which encourages academic excellence, enjoyment of learning, critical reasoning and inquiry," and
- *"retaining a core commitment to research-based teaching and enhancing scholarship through clearly linking research, professional practice and teaching."*

For the Networking Academy Program (Cisco Networking Academy Program, 1998), the teaching and learning goals are stated as follows:

> *To train knowledgeable students who can achieve the entry-level CCNA certification (which requires passing a multiple-choice exam) AND to produce empowered students who can design, install, and maintain networks typical of schools.*

While it is not a direct intention to attempt to reengineer traditional tertiary education (Berge, 2000), the two goals combine to represent an example of a degree/certification competency-based alternate model (Hanna, 1998) to traditional tertiary education. At issue is the need to ensure that the philosophical level of education that is provided is one of "transforming" students into autonomously capable professionals rather than teaching students to "conform" to employer direction (Bentley, Lowry, & Sandy, 1999).

A further set of challenges occurs when dealing with the treatment of assessment. For the Cisco Networking Academy Program, given its dual teaching and learning goals, the assessment goals (Cisco Networking Academy Program, 1998) are articulated as:

> *Dual assessment philosophy—a psychometrically-validated standardized multiple-choice testing system, and a spectrum of skills-based, lab-based, hands-on, troubleshooting, "authentic," journal-and-portfolio-based assessments.*

A decision was therefore required as to the contribution that skills exams make to a student's final grade. This is complicated by the fact that grading of skills exams within the traditional Cisco Networking Academy Program is conventionally set as either a pass or fail. An example is the successful construction of a CAT-5 data cable. In this environment, students must pass the skills exam as a prerequisite to completion of that stage of the program. Whatever the contribution that skills exams have in an undergraduate course, it is unlikely that it is significant. The current breakdown of assessment for both data communications courses is 50% for the external final exam, 20% for an internal midsemester course, and 30% that can be allocated to Cisco Networking Academy Program assessment components. The issue is that the skills can be perceived by students as an integral pathway to the attainment of employee-specific technical skills, and a balance is required between student perceptions of what employers want and what employers say they want in new graduates, which is often the ability of higher-order thinking. (Turner & Lowry, 1999)

It is difficult to find the proper balance between the introduction of general concepts and the teaching of more pragmatic skills that many students feel they need. This fact has been recognised for IT education (Banks, 2001; Bently et al., 1999; Turner & Lowry, 1999) and for tertiary students regardless of their discipline (Beyrouty, 2000; Shulman, 1997). It is equally challenging to pitch courses at a level that will keep students interested (Fallows & Ahmet, 1999). This paper presents a case where the combination of theoretical learning, lab experimentation, and group mini-projects (challenges) with traditional study techniques and testing was used with the goal of achieving a deeper level of understanding and learning.

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BIOGRAPHICAL SKETCHES

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Koro Tawa *(k.tawa@auckland.ac.nz) is a lecturer in Information Systems at the University of Auckland, New Zealand. He has worked as a consultant for a number of organisations in the area of Internet communications, and enterprise communications software. He teaches data communications and his research interests in data communications, distributed objects and digital commerce technologies. He received his Bachelor of Commerce degree in Information Systems from the University of Auckland (New Zealand) in 1999.*

APPENDIX 1

University Revenues and Expenditures—Year 2000

Source: The University of Auckland Budget 2002

REVENUES (NZ$000)	
Teaching and Research	269,320
Externally Funded Research	85,809
Other Operating Activities	80,277
Total	435,406
EXPENDITURES (NZ$000)	
Teaching and Research	205,959
Externally Funded Research	77,233
Other Operating Activities	143,133
Total	426,325

APPENDIX 2

Outline of the Data Communications Course in 2000

1. Introduction
2. The Signal and Information
3. Transmission Systems
4. Telecommunications Transmission Media
5. Communication Techniques
6. Networking Fundamentals
7. Switching Techniques
8. Introduction to the ISO/OSI Reference Model
9. Network Architectures
10. Wide-Area Networks
11. Internetworking
12. Local Area Networks
13. High-Speed Networking
14. Distributed Systems Applications

APPENDIX 3

Outline of the Advanced Data Communications Course in 2000

1. Interconnection Standards

[1] The Standards Committees
[2] X.200 Reference Model
[3] Physical Layer
[4] Link Layer
[5] Link Layer Technologies
[6] Network Layer
[7] Network Layer Technologies
[8] Transport Layer
[9] The Architecture of the Internet

2. Internetworking Standards

[10] The Upper Layers of the OSI Reference Model
[11] The Session Layer
[12] The Presentation Layer
[13] Security and Electronic Commerce Technology Review

3. Application Standards

[14] Introduction to Abstract Syntax
[15] Introductory Elements of the Application Standards
[16] Introduction to OSI Network Management

4. Object Oriented Network Modeling

[17] Introduction to Network Modeling
[18] Object Inheritance, Aggregation and Registration Hierarchies
[19] Topics in Network Modeling
[20] Application of the Techniques