Teaching the process skills - an ICIS experience

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ABSTRACT

Conventional education methods are well established in teaching theory and concepts. The emphasis is on understanding. The problem of how to integrate different areas of knowledge, adapt certain process, and apply onto a specific problem, is usually left to the on-the-job-training, under the name of experience. The learning curve of this "experience" is usually steep, and unguided. This is especially true for the Software Engineering profession, where human activities contribute a major percentage, which are normally not taught.

Information Communication Institute of Singapore (ICIS), a collaboration between the Singapore National Computer Board and AT&T [1], is an educational institute offering Master Degree courses in Communication Software. The objective is to produce communication software specialists to spearhead the nation's information communication technology industry. The challenge is the need for the specialists produced to be productive immediately after they graduated from the Institute. This requires a course that teaches the in-depth knowledge in the three critical technologies for communication software, viz. communication, software engineering and platform technologies; as well as a good controlled hands-on environment for the students to integrate their knowledge, experience the real communication software development processes and practise the complex human interaction skills in a large software development project team. With these requirements in mind, an unique 12-month full-time programme was established in 1989 and first batch of students were admitted in Jan 1990. This paper will present this unique programme, and the experience of its planning and implementation.

1. THE NEED FOR IT SPECIALIST MANPOWER

Being a small country endowed with no natural resources, Singapore can only invest in the precious resources that she has - human resources. Singapore has to adopt a different approach in planning and fuelling her economic development. A major economic direction that Singapore has been embarking for the last 10 to 15 years is to

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move to higher value-added services. Information Technology (IT) plays a very important role in this economic thrust. The thrust in the IT arena is to make Singapore a world class exploiter of IT and eventually become a world class provider of IT products and services. In 1985, a National IT Plan (NITP) [2] was prepared by the Committee for National Computerisation (CNC). In the NITP, seven main building blocks were identified as strategic for Singapore to achieve her IT goal:

- IT manpower
- IT culture
- Information communication infrastructure
- IT application
- IT industry
- Climate for creativity and enterprise
- Coordination and collaboration

Different activities were put in motion to identify the needs in these seven building blocks. Amongst the key activities in the IT manpower area, one was to address the need for specialist manpower in communication software. It was established that an ideal profile of a communication specialist would be one having a hybrid of Electrical Engineering and Computer Science knowledge; creativity; project management skills; and human communication skills. The specialist is further credited by a strong quality orientation as well as experience in business applications. This is the ideal person that will help establish Singapore's communication software industry. However, without an established industry, it was difficult to find such person that possess the profile. One way to break this vicious circle is to create a critical mass of the required professionals through education and training. It is with this objective in mind that ICIS was formed. Its mission is to produce the needed communications software specialists in time to allow Singapore to fact her challenges in the coming years.

2. PROFILE OF A COMMUNICATION SOFTWARE SPECIALIST

In order to produce a quality product, it is imperative to have a correct specification of customer's requirements. In the same token, in order to design a specialist training programme that will properly address the national manpower needs, the first and foremost important step would be to specify the profile of a specialist - the end product specification. A profile for the communication software specialists has therefore been compiled as a standard measurement for the design of a useful, effective specialist training programme. The profile is categorised into experience, ability, and qualification.

It is envisaged that at the end of the training, the specialist should have gone through the experience of

- Handling large (up to 15 man-year) real life complex project
- Working in large (up to 25 people) project team
- Hands-on the complete software development life cycle
- Applying quality-oriented process to information communication project
- Practising project management skills, team work skills, and interpersonal skills
- Exposure in the relevant technology
- Using a project methodology

Also, the specialists would be able to

- Independently identify a technology problem area or business opportunity, develop a solution, and finally formulate a project to implement the solution
- Apply and implement technology
- Integrate telecommunication technology with software development technology
- Integrate knowledge and process
- Set up and apply quality process
- Manage projects from a management perspective
- Organise and carry out a research project independently or in group
- Be sensitive to business and technology opportunity in communication software development.

Finally, the specialist's qualification

- Attain a Master degree equivalent level of knowledge
- Capable to further into more advance level of research
- Professional body recognition

To produce specialists that possess the aggressive ideal professional profile and to meet the objective of providing strong industrial-oriented kind of training with specialisation in a specific IT area of communication software has resulted in a demanding 12-month full-time Master Degree programme. The course is characterised by two major components - intensive knowledge acquisition through classroom lectures and a 10-month communication software project. Both run concurrently over the twelve months course duration. Time spent in classroom lectures total to three hundred hours while the software project to five hundred hours. The programme admits experienced electrical/electronics engineers and computer scientists/systems analysts to form a class of about 25 students. An unique communication software project requires the entire class of students to form a project team to develop a real-life communication software system. Through this project (or known as the Practicum), students integrate their technical knowledge learned in the course and experience through a complete software development life cycle. The details of the lectures and practicum are given in the next two Sections.

3.   KNOWLEDGE ACQUISITION

At ICIS, we define a Communication Software Specialist as a specialist who possesses in-depth knowledge in at least 3 areas of technology, viz communication technology, software development process technology and platform technology.   In-depth knowledge of communication technology is needed since the product that is being designed and built is a communication system. Since the focus is on communication software, the specialist needs to have thorough knowledge of the software development process used in building the software. To realise the design, proficiency in an implementation environment is required.   The last we termed as platform technology. The need to equip specialists with the three types of technology has in main driven the structure of the curriculum. Specialists cover modules pertaining to each area of technology throughout the entire programme. A brief listing of the subjects covered in each area is now given.

In communication technology, topics covered include major functions of a network (transmission, switching, signalling), network applications and services, traffic engineering, networking standards, major network architectures, major networking

products, and modelling and analysis of communication systems and networks. Percentage of lectures time in this area take up 27% of the total classroom hours. In addition, specialists need to have further in-depth knowledge in areas of networking protocols, network programming and device driver development, network planning and design techniques, queuing and graph theory, simulation, network management concepts and applications. These advanced topics are covered in another 23% of the total classroom lecture hours.

In software development process technology, the aim is two fold. First, to train specialists in the area of software project management. The emphasis is on how to manage a large software project and produce a quality product. Specialists are given a firm grounding in concepts and techniques used in project management, quality management, and configuration management. Second, to equip specialists with the technical development knowledge which include methodologies, tools and techniques needed to design and build complex software systems. The methodologies, tools and techniques cover the entire software development life cycle starting from requirements analysis to technical specification, to design, coding, and testing. Percentage of lectures time in this area take up 33% of the total classroom hours.

In platform technology, specialists are required to master an implementation language. The language of choice is C and the platform is the UNIX operating system. Specialists need to make C system calls into the UNIX kernel to develop communication software that operates in real time multi-user and multi-tasking environments. Specialists will also receive training in developing graphical user interface applications in the X-window environment. Percentage of lectures time in this area take up 17% of the total classroom hours.

Having knowledge in these 3 areas alone is not sufficient to qualify a person as a communication software specialist. Instead, specialists would need to possess hands-on experience in designing and building a complex communication software system and in doing so experience the full software development life cycle. This valuable experience will equip the specialist with the knowledge and skills needed to do the job at each stage of the software development in future projects. With ICIS' experience as hindsight, he can better plan for tasks ahead and avoid pitfalls. He can take preemptive measures to avoid making the same mistakes which he had made during the programme at ICIS. How classroom training being reinforced through application will be the subject of the next Section.

4.   KNOWLEDGE INTERNALISATION

In the previous Section, a communication software specialist is being defined as someone who possesses in-depth knowledge in three technology areas viz communication technology, software technology, and platform technology. ICIS imparts these knowledge to the student through classroom training and laboratory sessions. However, having in-depth knowledge in these three areas is only the first step and is not sufficient to produce a communication software specialist. What differentiate a specialist from an academician is the internalisation and integration of knowledge through application. The ICIS training programme is unique due to the fact that it has to meet very specific needs for producing communication software specialists. The uniqueness stems from the way the programme combines structured learning with near-life project experience - the practicum. The knowledge that the

students gain in class will be used in a timely manner throughout the year long practicum. The characteristics of the ICIS practicum is described below.

Practicum Integrates The Three Technology Areas

Already, computers no longer operate in isolation, but form parts of large global networks. With the introduction of new infrastructure such as the ISDN, new integrated IT applications is now in great demand. The success of such applications lies in software which integrate software and communication technologies and being built on a specific platform. This integration is best brought about by actually going through a project - experiencing a full development life cycle of developing a communication software product on a specific operation platform (Figure 1). In the past, the practicum has built products such as TCP/IP on ISDN, X.25 Switches, and LAN/WAN simulators.
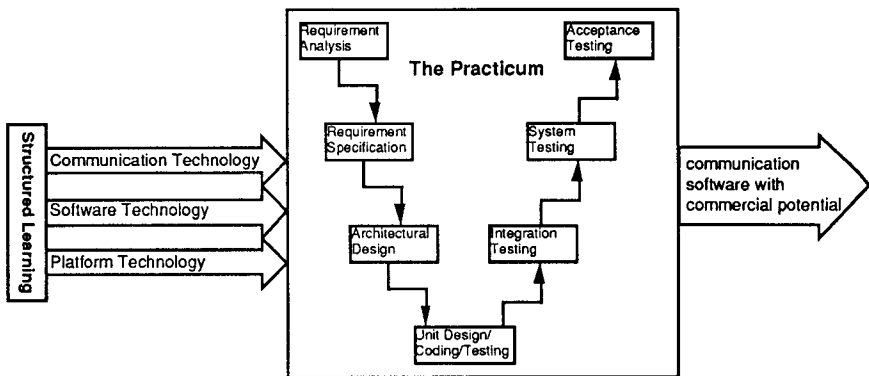

Figure 1 - Integration Of Technologies Through Application

Practicum Emphasises On Process Discipline

The practicum puts a lot of emphasis on the importance of management processes to ensure that students pay equal attention to such activities as project management, quality assurance, and configuration management, as well as technical development such as analysis, design, and implementation. This is to ensure that students will not only learn how to apply the hard skills into designing and developing the software product, but also experience the importance of managing the project for time, schedule, resources, and quality.

Practicum Combines Hard And Soft Skills

Apart from technology and process skills, the programme also imparts soft skills to students such as teamwork, leadership, quality orientation, decision making, conflict resolution, documentation needs, and interpersonal communication. While hard skills are achieved through lectures, the soft skills are imparted through the practicum where the whole class of around 25 students participate in one project team, learning to work together as a team producing a single software product. Furthermore, the whole project team is further divided into sub-teams dealing with different aspects of the project depending on the phase that the project is in. For example, at the requirement specification phase, sub-team will be formed to tackle requirements specification,

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project management, quality assurance, configuration management, and system support. Throughout the practicum, students are required to change roles at some logical points. Each student will be given the opportunity to be in the leadership role as well as in different sub-teams.

Specialisation On Communication Technology

Information communication, being defined in ICIS as the movement and management of information, covers a very broad spectrum of knowledge areas. Therefore further specialisation is needed in order that the specialists can explore the technology effectively (Figure 2). At ICIS, communication technology is further categorised into three areas - data communication and networking, network planning and design, and network management. Specialists with specific communication knowledge and experience will need to work side-by-side to make the whole network alive. A data communication network specialist is concerned with how to move the information from workstation A to workstation B. A network planning specialist plans for a cost-effective, reliable network to move information from point A to point B. Finally, the network management specialist ensures that the network resources is being employed effectively and efficiently. The specialisation modules occupies 20% of the study load. However, every student will be taught the foundational knowledge on communication.
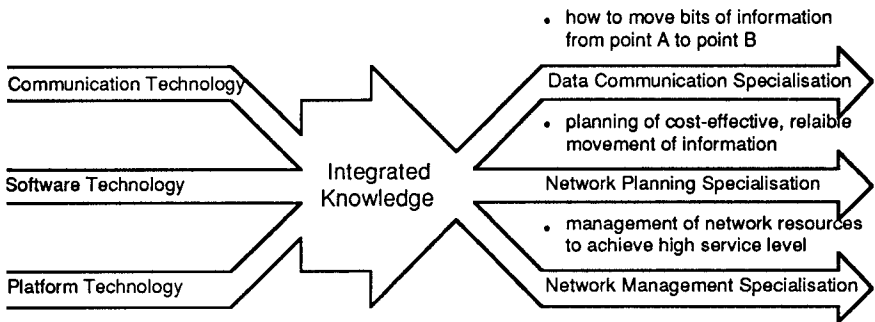

- how to move bits of information from point A to point B

Communication Technology → Data Communication Specialisation

- planning of cost-effective, relaible movement of information

Software Technology → Integrated Knowledge → Network Planning Specialisation

- management of network resources to achieve high service level

Platform Technology → Network Management Specialisation

Figure 2 - Communication Technology Specialisation

Locked Step

In order to facilitate the application of what students have learned from the classes in the practicum in a timely manner, the curriculum has been designed in such a way that the classroom modules and the practicum activities are in locked steps. That is, students learn something in class today and they will get the opportunity to apply it in the practicum tomorrow. In this way, students quickly reinforce what they have just learned. In practice, courses relevant to the need of the software development life cycle phase will be taught just prior to the commencement of the phase work.

Students Managing The Practicum

In the practicum, students organise themselves into teams with ICIS faculty providing the assistance. By and large, students decide what group they should have, who are the project manager and team leaders, who are the members, and what are the decision and communication processes. They also draw up their own schedule,

allocate resources, and determine their working style. Since the project is a large project with 25 persons lasting for almost a year. Students will therefore benefit tremendously from the challenges of managing a project of such magnitude. They will also learn how to manage groups of people with different background, experience, capability, and personality. However, they will not be left alone without expert help. A Management Steering Committee (MSC) comprising of 5 or more faculty will take the responsibility to oversee the practicum. MSC will meet with the project management office regularly to provide feedback and guidance. Each member in the MSC will also have an added responsibility to oversee the progress of at least one sub-team.

5. CROSSING THE FINISH LINE

5.1 PREREQUISITE

With the inherent complexity of the programme, the amount of cross disciplinary knowledge to be acquired, and the need to be able to apply such knowledge within a short time, the programme necessarily requires the students to already possess some fundamental knowledge in either of the three technology areas viz communication technology, software development process technology and platform technology. If a student has prior knowledge and experience in at least one of the areas, he/she could spend more time in areas that he/she is unfamiliar with. At the same time, track record of proven academic capability is essential to avoid enrolling students who later might have difficulty in picking up technically demanding material quickly within the time given. A prerequisite is hence set, requiring either a Bachelor degree in Electronics Engineering or Bachelor degree in Computer Science, both with second class honours or with a minimum GPA of 2.0 out of a total of 4.0. In addition, knowledge of the C programming language is assumed.

It is beneficial to have students with cross discipline in a class. They are able to contribute by offering different views on various subjects and in the process learn from each other. Experience tells us that the thinking approach employed by Engineers and Computer Scientists are often quite different and mixing them in a class and projects could stimulate creativity and widen understanding.

In a loaded programme like this, quite often self motivation is an important force that keeps the students going for 12 months. Many of the students have to make sacrifices in their social life and make adjustments. Making sure that a potential candidate has the right motivation and attitude towards the programme is an important step in reducing the number of students in class who are "looking for a break" from work. These students often do not work well with others since they do not share the same objectives as rest of the class. This will be most evident during the practicum and the rest of the students will have to bear the load of these "hitch hikers".

An effective, though labour intensive method of ascertaining the technical competence, motivation and attitude of potential students is to have a face-to-face interview with them conducted by the faculty members. The average duration of an interview is about 1.5 to 2 hours. Questions on technical areas as well as personal attitude, motivation are asked during the interview. A C language proficiency test is also taken by all candidates who passed the interview. Those who do not achieve the required proficiency in C language will have to take a C course before the commencement of the actual programme.

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5.2   ASSESSMENT

The purpose of assessment is three-fold, it serves as a feedback to the students on their proficiency level; as a mechanism to motivate the students to excel in the areas of study; and as a report to sponsoring company which have employees enrolled in the programme. In line with the programme's emphasis on practical orientation, the mode of assessment reinforces the understanding and application of knowledge. Depending on the module, the assessment may take the form of assignment, small project, examination, or a combination of the three.

Assignments are homework or exercises given to the student either to be completed by an individual or by small group of two to three. The assignments aim to let students exercise application of the knowledge learnt in a specific area. Small projects, on the other hand, require students to apply their knowledge in multiple areas to solve a more broadly defined problem. This is normally done by larger groups of three to five students. In addition to a report to be submitted, students are required to make presentations of their solutions to the class and faculty members. All examinations in the programme are open book examinations. This is to re-emphasise the principle of testing students on understanding and application than the ability to memorise facts. Also the practice is closer to real world as in most of the time in life, you have access to some kind of reference material.

Another form of assessment is class participation. Students are strongly encouraged to participate in class. Ask questions, share experience, raise comments, provide alternatives. The levels of individual class participation are formally recorded and they contribute to the student's final module grade. Students are being impressed upon at the start of the programme that it is very important for them in to be able to notice ambiguity in an argument, formulate question to clarify, express a view and opinion in an acceptable manner in public meetings.

Group assessment also helps to enhance team spirit. Group effort are assessed by deliverables produced by the group, based on quality of the solution and overall presentation. Everyone in the team receives the same group grade as they have to work as a team. Team work includes coordination, distribution of work and compilation of final solution. However, individual effort, ability and contribution is also acknowledged by awarding individual credit on top of the group grade.

In Practicum, assessment is more complex. MSC members will observe working meetings and note the contribution of each student. Regular formal feedback forms and status meetings with the students are used as assessment inputs. Typically at the end of each quarter, MSC members meet to discuss the performance of each student in the practicum, using the input supplied by these forms as well as the contacts and observations that the members have of the individual through numerous review sessions and discussions with the project management office. Fully aware of the difficulty of assessing the performance of the individual in a project where teamwork is stressed and where the whole project is being shouldered by the entire class, using quantitative measures for the individual is considered only as a last resort. A consensus is sought for a qualitative grade to be assigned to the student. Using consensus building as well as student feedback, it is possible to avoid personal favourites and isolated viewpoints. Precise assessment is not possible and subjective judgment is necessary.

5.3   QUALIFICATION

With the kind of breadth and depth of knowledge covered in the programme, the unique Practicum that integrates the 3 areas of knowledge learned and the heavy emphasis of understanding and application of it, the programme has all the qualities of a postgraduate programme. This justifies the prerequisite of a BSc Honours degree for the programme. Since only Government Gazetted tertiary institutions are allowed to award former degrees in Singapore, graduates of the programme were awarded Postgraduate Diploma until the official accreditation of the programme by the University of Essex, UK in 1992. From then onwards, all qualified graduates of the programme receive a MSc degree in Communication Software Management from the University of Essex as well as the Postgraduate Diploma for Communication Software from ICIS.

6   CONCLUSION

The ICIS programme is unique. The word that best explain this uniqueness is integration. The programme integrates education and training. Education is the transfer of knowledge done in the classrooms. However, specialists cannot be made through education alone. They need to be trained on the process of doing things, how to get the process right so that they can produce quality output every time. Integration is achieved through the practicum which combines classroom teaching with rigorous hands-on practice.

The programme also integrate two disciplines, electrical engineering and computer science. In so doing, the training integrates communication technology with software engineering process technology. These two disciplines are critical ingredients in communication software development. In order to achieve such integration in a span of 1 year, the ICIS programme has necessary to be tough and demanding.

To enhance and improve the programme, ICIS actively and constantly seeks feedback from students during the duration of the course. Such feedback has enabled ICIS to consolidate and improve the programme to benefit successive batches of students. To date, 193 specialists have graduated from the ICIS programme. These specialists are presently pursuing challenging careers in a variety of jobs, ranging from communication software development, networking consultancy, systems integration, systems support to MIS system analysis. From feedback through direct contact with organisations employing ICIS graduates as well as the graduates themselves during alumni gatherings, the specialists are doing very well. They have been able to demonstrate sound technical competence in their work, good planning ability and communication skills. In addition, having gone through a full software development life cycle, they were able to lead project teams comfortably in developing software product. They proved to be better managers as well as team players. Through their good performance, ICIS' reputation has been steadily increasing and this has in turn made the programme more established in the market place.

REFERENCES

[1]   "Agreement For The Establishment Of The Information Communication Institute of Singapore", National Computer Board And AT&T International Inc, 17 Oct 88

[2]   "National IT Plan - A Strategic Framework", Committee For National Computerisation Working Committee, November 1985