A Client-focussed, Team-of-Teams Approach to Software Development Projects

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Abstract

This paper describes an innovative and very successful final year project course that has been provided in the Department of Computer Science over the past four years. Students are formed into relatively large teams of 16 and tackle a challenging, realistic project during a single semester. Unlike many computer science project courses that emphasise the technical issues, to the detriment of the end-user, this course is focussed on the people involved in the project and the client. The project team is highly structured and team members take on all of the roles that one is likely to encounter in projects in the workplace.

1. Introduction

It is considered highly desirable that all undergraduate students have some form of large project experience before graduating [1,11]. However, it is virtually impossible to replicate the workplace within a university course. Time constraints, variability of experience, equipment, the work environment and knowledgeable project managers are not readily available to construct an artificial project team. Further, the cost to create such an environment for most university departments would be prohibitive in the provision of equipment, office space and in the hiring of suitable personnel. Some universities overcome this by having a sandwiched year of industrial experience in their undergraduate program. For example, the Bachelor of Information Technology degree, taught by the School of Computing Sciences, at the University of Technology, Sydney, requires students to have a year of industrial experience during their undergraduate program.

A major issue in designing software engineering and information systems curricula then becomes: What aspects of the real world project do we consider most important for student to experience before graduation?

Surveys of employers have shown that the qualities that they consistently favour most highly in graduates relate to their communication skills, their ability to work together in teams and their technical writing skills, besides their basic technical knowledge [2,5]. In the former Department of Computer Science, education and training in professional skills and knowledge has been introduced at all undergraduate and honours levels over the past three years. In the final year project course it is then appropriate that the project structure, coordination and training focus on the professional and inter-personal issues associated with systems development.

2. Background

The Business/Higher Education Round Table [2] conducted a survey in 1992 in which both businesses and universities were asked to rank the desired characteristics of university graduates. The results are shown in Table 1.

Desired Characteristics of Graduates	Rank Business	University
Communication skills	1	7
Capacity to learn new skills and procedures	2	5
Capacity for cooperation and teamwork	3	8
Capacity to make decision and solve problems	4	3
Ability to apply knowledge to workplace	5	4
Capacity to work with minimum supervision	6	6
Theoretical knowledge in a professional field	7	1
Capacity to use computer technology	8	2
Understanding of business ethics	9	12
General business knowledge	10	11
Specific work skills	11	9
A broad background of general knowledge	12	10

Table 1. Desired Characteristics of University Graduates

This survey indicates that business and universities differ in their ranking of the importance of characteristics in the graduates in two major areas:

1. Communication skills, a capacity to learn new skills and procedures, and a capacity for cooperation and teamwork. In each of these cases the universitiesÕ rankings are well below those of business, particularly in the area of communication skills.
2. Theoretical knowledge in a professional field and a capacity to use computer technology. In these cases universities have rated these characteristics much higher than has business.

Further the Business/Higher Education Round Table [2] suggests that universities currently produce students who are:

- curriculum driven
- used to solving problems in a theoretical coherent framework
- used to a classroom setting in which instructors instruct and learners learn
- used to working towards pre-set educational objectives
- used to expressing thoughts, ideas, opinions, and solutions in written form
- competitive on his or her own behalf, pursuing personal goals such as awards, accreditation and prizes
- lacking in well-developed interpersonal skills

In contrast the Business/Higher Education Round Table suggest that the workplace requires graduates who are:

- competent at problem-based learning
- literate across a broad range of disciplines, but with appropriate specialised knowledge/skills
- used to expressing thoughts, ideas, opinions, and solutions orally
- used to making oral submissions and written reports at short notice
- competitive on behalf of the team or organisation, pursuing company/group goals
- possessing highly-developed interpersonal skills

A survey by the Australian Department of Education, Employment and Training [5] in 1990 asked 226 IT professionals to rank a list of tasks according to how essential they consider they were to the performance of their jobs. The 12 most essential tasks from this survey are shown in table 2.

In this survey only 8% of respondents indicated that they had learnt how to determine client needs from formal academic training, and just 2% had learnt how to establish a project team from academic training.

Task	Essential	Mean time spent (hrs/week)
Determine clients needs	91%	2.45
Identify information strategy	91%	2.51
Identify problems in system	94%	2.69
Establish project team	93%	2.33
Define process functions	92%	2.73
Correct errors, testing	93%	2.57
Establish restore procedure	94%	2.15
Implement logic	91%	2.68
Write program from specifications	90%	2.93
Perform acceptance test	92%	2.29
Assist users	90%	3.07
Run help desk	90%	3.10

Table 2. Essential Tasks of IT Professionals

Little states that

> No amount of learning *about* something will, alone, prepare a student adequately to practise a particular skill or to make use of knowledge in a sensible, appropriate, and effective way. This is even more so when the learning in question concerns the design, development, and operation of computer-based information systems [9, p131]

Clearly there are significant short-comings in the traditional approach of exposing students to large software projects as part of their undergraduate experience. If we are to produce students who have the appropriate attitude to accept readily the nature of the workplace into which they are graduating, then we need to emphasise communication, teamwork and having a client focus in their undergraduate projects. One should not expect a university education to be an apprenticeship, nor should one expect university education to be intensive skills training. However, exposure to the most important professional skills can significantly enhance studentsÕ employment opportunities, and prepare them to have an open mind to the demands placed upon them by employers. Recent correspondence [3] from a recruitment agency, working on behalf of Telstra, contained the following assessment of IT graduates from the University of Tasmania:

> Of the 18 applications we received from the University of Tasmania for Telstra Graduate Opportunities, 9 applicants were listed for first interviews. ... While undeniably important, technical knowledge forms but part of the attributes we expect from a graduate. ... We were particularly impressed by the Tasmanian graduates, who were able to demonstrate a high standard in all of the selection criteria.

This trend towards increasing importance of non-technical attributes is also supported by a survey of IS job advertisements that appeared in the Australian newspaper over the past 20 years [12].

3. Specific Issues for Systems Development

Lai [7] has distinguished the mechanical aspects of systems development from the human aspects. She lists the mechanical aspects as:

¥ Time controlÑscheduling

The use of a variety of scheduling and resource management tools to ensure that the time line of a project is tracked and the project is completed within a reasonable time.

¥ Cost controlÑbudgeting and variance analysis

These aspects focus on the use of methods for estimation of expected resource usage, and the development of resource budgets for a project.

¥ Performance controlÑquality assurance process

The use of those techniques and methods which contribute to the craft of analysing, designing and implementing software systems. These techniques include the use of specific development methodologies, work structure breakdown and compliance testing.

However, the adoption of best practice with respect to the above three areas does not ensure successful systems development. A number of other human-oriented characteristics are essential for good systems development. Lai [7] identifies these as:

¥ Project Managers as Team Builders

Project managers need to build project teams in which individuals are free to contribute to the best of their ability as individuals, but also contribute to the outcome of the project as part of the team. The team then has a degree of synergy in achieving more than the sum of the outputs of its individuals.

¥ Complementarity

Each member of the project team has a specific job to do and a specific role to play. The team builder aims to achieve both unity and greater output through encouraging diverse thinking. A key part of the complementarity aspect is that each team member recognises the individual strengths of others and reinforces those strengths.

¥ Communication

Pathways of communication need to be well established, both vertically from the team leader to the team members, and also horizontally between team members. Increased communication leads to greater collaborative effort.

¥ Commitment

Team members need to become committed to the team, and not just their own personal goals. They need to recognise that the synergy of the team, and hence they will obtain greater rewards through commitment to the project team.

A major challenge for software engineering and information systems educators is to transfer the wisdom associated with these human-oriented characteristics of systems development, while also teaching students the technical, mechanical and managerial aspects of systems development and project management. Because of time and resource constraints, all of this has to be done within a very short period of time, typically 10-14 weeks, and in the highly artificial environment of the university teaching and research laboratories. With current levels of funding university laboratories frequently are well behind the latest technology, and sometimes methodologies, being employed in industry.

Zahniser [13] has described a Teams-of-Teams approach to software analysis and design, called Design by Walking Around (DBWA). He claims that this approach can dramatically cut software design time to a quarter of that required by traditional, sequential approaches. The DBWA approach requires that team members make three paradigm shifts:

1. From independent knowledge workers to a cross-functional team

   This paradigm shift is consistent with a recognition of LaiÕs [7] human-oriented aspects of project teams.

   In particular, Zahniser focuses on the creation and maintenance of Group Memory as being the key to making the team-of-teams approach work. This group memory is essentially the collective consciousness of the project team, as it learns about the problem, shares information, and proposes and tests solutions. A high level of communication is required to ensure that all members of the group properly contribute and have access to this accumulating group memory.

2. From two-dimensional to multi-dimensional system modelling

   This paradigm shift is essentially the adoption of rich, hyperview system models, rather than being limited to simple, two-dimensional models, such as functional decomposition diagrams. Further, designers are encouraged to consider a particular system design from the different viewpoints of many models, rather than from a single modelling technique or methodology.

3. From linear to concurrent development

   Rather than the project proceeding along essentially a linear sequence of tasks, maximum concurrency is encouraged between subteams and individuals. This necessitates high degrees of communication and

project coordination on the part of the project team leader.

4. Course Structure

The IT Project course at the University of Tasmania has been offered in the former Department of Computer Science and the new Department of Information Systems for four years, since 1994. This course is of one semester, or 14 weeks, in duration and is offered in the final semester of the three year degree. The course has been weighted at 8.33% of a full-time yearÕs workload.

The course has two prerequisites:

1. A second year Information Systems course which includes a topic on systems development methodologies. Students are exposed to a wide range of analysis and design methodologies, including Soft Systems Methodology [4] and ETHICS [10].
2. A first semester, third year course on IT Project Management. This course covers the essentials of IT project management, including the human aspects of team building, working in teams and appropriate incentive and rewards schemes for IT project teams.

Students who take the IT Project course are enrolled in a diverse range of degrees, including Bachelor of Arts, Bachelor of Computing, Bachelor of Economics and Bachelor of Science. This diversity is recognised in the course and the consequent diverse strengths of students is emphasised as an asset of the project teams.

All students taking the current IT Project course have completed two and half years (5 semesters) of professional development. This education and training in professional skills and knowledge is a core part of the IS program [8]. Each student is expected to attend a one hour workshop each fortnight throughout their undergraduate degree. These workshops cover a wide range of issues, including study skills, cross-cultural communication, inter-personal communication, information gathering, interviewing, formation of teams, working in teams, team leadership, group problem solving techniques, presentation skills, conflict resolution and negotiation, and career visualisation. The coverage of these topics is closely linked to the remainder of the courses, so that students see these workshops as being highly relevant to the IS course and to their future careers.

The IT Project course is an intensive practical project course in which the final grade for each student is 100% based on continuing assessment of the performance of individuals, teams and subteams during the semester. The assessment of each student is determined by a combination of individual, subteam and team-based achievements, and is accumulated throughout the semester.

Each student is expected to spend at least 50 hours on the project over the duration of one semester of 14 weeks. This involvement is consistent with the weighting assigned to the course.

The framework for this IT Project course was originally proposed by Chris Keen, using the concept of student experts, and the project concepts from the Project Management course. Carmen Lockwood has been responsible for the delivery of the course since its inception, and for much of the detail of the course, including the adoption of the team-of-teams approach. John Lamp has assisted in the development of the course, has acted as a project client on occasions, and has been primarily responsible for the detailed design and delivery of much of the professional development workshops in the IS program.

5. Client Focus

Each year the IT Project course has been taught, a different project topic has been used. These project topics and objectives are chosen to be

¥ relatively open ended

Students are encouraged to strive to achieve as much as possible in the time permitted, rather than being limited by the project goals.

¥ challenging

The topic and scope of the project is chosen to extend the students well beyond their previous experience in practical assignments. Typically the students have not previously been exposed to the software and many of the technical concepts employed in the problem domain of the project.

For example, in some years students have been given projects in the design and markup of Standard Generalised Markup Language (SGML) [6]. At the commencement of the project none of the students involved had any previous knowledge of the SGML standard, nor of the design and use of Document Type Definitions (DTDs).

¥ aimed at the production of proof of concept systems, rather than fully developed solutions

The systems developed by the students need to be fully tested, but do not have to reflect the full functionality and employ all of the live data of a commercially developed system. In all other aspects, however, the nature of the problem and the expectations of the students are structured to be as realistic as possible.

For example, in one year students were required to develop a WWW display system for the foyer of the Department of Computer Science. The system developed incorporated an enquiry and data entry facility for undergraduate students to check and alter their tutorial times. With some refinement by Department technical staff, this system has been in operation since the completion of that project.

The topics chosen for projects are:

1994 WWW display system for Department foyer

1995 SGML DTD design and markup of sections of the University Handbook

1996 SGML DTD design and markup of
a. Sections of the University Handbook
b. Journals for the Centre for Youth Studies

1997 Database of University course information

The project for a particular year is chosen to use concepts covered in the undergraduate curriculum (databases, information management) but using software not previously encountered.

Each project has a specific, real client, to whom the project results are to be delivered. This client is chosen by the course coordinator as part of the project design, and may be from industry or from within the University.

Students are strongly encouraged to be client focussed throughout the project by adoption of the following criteria:

- Close interaction must be maintained with the client throughout all phases of the project
- The client and students have joint ownership in the project and its outcomes
- All key decisions affecting the output of the project must be made in consultation with the client

The client is interviewed by the course coordinator at the end of the project on their perceptions and, in particular, the above criteria and this feedback influences the marks allocated to the subteams.

Further, the project subteams are expected to resolve their own interpersonal problems through conflict resolution and negotiation techniques. They may not pass these problems on to the client. The course coordinator only intervenes in matters of an interpersonal or team-work nature when absolutely necessary.

At the commencement of the course students receive a one sentence outline of the project from the course coordinator. All subsequent project and requirements definition is obtained directly from the project client.

6. Team-of-Teams Composition

The team-of-teams approach for the IT Project course is based on a total team size of approximately 16 students, although it would be feasible to run this approach with 12-20 students per team. Each team has the structure shown in Figure 1.

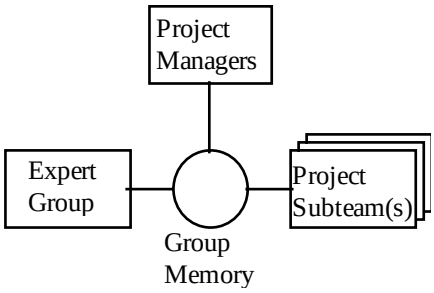

Figure 1. Team-of-Teams Structure

Each team has the same overall structure, although the actual numbers assigned to each subteam may vary with the problem area and number of enrolled students.

There is a group of 2-3 Project Managers whose primary task is to oversee the conduct of the entire project, and manage the mechanical aspects of the project, such as resource allocation, task assignment and scheduling, and maintenance of project monitoring documentation. Project Managers should be good communicators, but not be domineering.

There is a group of 2-3 Experts who are required to study the appropriate technology and tools required for the execution of the project. These students need to master the technical material very early in the project life cycle, so that they can act as consultants to the project subteams later, during the design and implementation phases. Experts should be good at gathering and assimilating new material, and be capable of effectively communicating what they have learnt to others.

The remaining team members are split into Project Subteams, with 3-4 students per subteam. These students will perform the bulk of the project definition, analysis, design and implementation.

Students are assigned teams and subteams by the course coordinator. Prior to commencement of the IS Project course the course coordinator discusses the enrolled students with other lecturers, and examines the academic record of these students. The Expert Group and Project Managers are assigned students with better track records in technical or interpersonal skills. Other key students are identified who have good academic records, and these students are distributed evenly across the various subteams. As much as possible the teams and subteams are structured to be equitable in gender, ethnic background and academic ability. In particular, friends and close relatives are split across subteams.

7. Team-of-Teams Process

The composition of the teams and subteams are established in the first session of the course. The clientÕs contact details and the project description are distributed, together with an outline of the roles of the subteams.

The Project Subteams then commence the work of developing the project definition or brief, and

progressing to the preliminary design of the project. Each Project Subteam completes this exercise in parallel. The basic waterfall model is employed for the systems development life cycle, although students are free to deviate from this general methodology if they wish.

The Project Managers act as the quality controllers in this phase, by giving the Project Subteams feedback on their project briefs and preliminary designs. In addition, the Project Managers liaise closely with the client during this phase to ensure that the designs satisfy the clientÕs requirements.

The Expert Group are meanwhile becoming familiar with the relevant technical material, reading manuals and associated documentation, and using software tools. For example, during the SGML projects the Expert Group had to study SGML markup and design, be capable of offering advice on the construction of Document Type Definitions, and be proficient in the use of SGML-Author and Near-&-Far editors.

During this initial phase the subteam members learn to work closely with one another, and also to share information and resources with other subteams. The subteams are not encouraged to be competitive.

The whole team then meets to discuss the various preliminary designs, and select what they consider to be the most appropriate design.

The second phase of the project has the Project Subteams working on the variety of tasks needed for the project. The Project Managers determine the tasks required to complete the project, assign tasks to the Project Subteams and develop a task schedule. They may wish to restructure the Project Subteams, depending on the complexity of the various tasks. As much as possible concurrency of task execution is encouraged, with information sharing between Project Subteams coordinated by the Project Managers.

The Expert Group members act as technical consultants to the other Project Subteams. Some years they have chosen to present a seminar to the other Project Subteams on the technical issues involved.

Experience of this approach over several years has identified some of the same problems inherent in most student projects:

- a small number of students do not pull their weight, and are penalised for their lack of effort. Every attempt is made to ensure that this does not disadvantage other students.
- during the project many students complain that it is too much work, although at the end of the course most agree that the time spent is close to the 50 hours specified at the commencement of the course.
- many students are unaccustomed to working on a single project for a 14 week semester. They are more familiar with completing short practical assignments that are then discarded.

8. Assessment of Students

The assessment of students is based on combined team and individual efforts. This is summarised in Table 3.

Assessment For Project Subteams	
Business Plan (B)	10% for each subteam
Preliminary Design (P)	10% for each subteam
Final Design (FD)	5% team mark
Implementation and Testing (I)	30% team mark
Documentation (DC)	10% team mark
Individual Report (IR)	15% for each individual
Reviews/Walkthroughs	20% for each individual
Assessment For Expert Group	
DTD (D1 & D2)	25% group mark
Aggregate mark	40% based on the marks obtained by the Project Subteams (for assessments of FD, I and DC) and evaluation of the Expert Group by the Project Subteams
Individual Report (IR)	15% for each individual
Reviews/Walkthroughs	20% for each individual
Assessment For Project Managers	
Evaluation, Plan, Progress Report (E & PP & PR)	25% group mark
Aggregate mark	40% based on the marks obtained by the Project Subteams (for assessments of FD, I and DC) and evaluation of the Project ManagersÕ Group by the Project Subteams
Individual Report (IR)	15% for each individual
Reviews/Walkthroughs	20% for each individual

Table 3. IT Project Assessment Scheme

As can be seen the marking scheme has components for individual, team and subteam marks. Also a component of the mark for the Project Managers and Experts is based on the overall team aggregate mark and an assessment of these groupsÕ performances by the other students.

9. Course Evaluation

The IT Project course is evaluated by the students at the completion of the semester, using the University of TasmaniaÕs standard Student Evaluation of Teaching and Learning (SETL) questionnaire.

In 1995 the IT Project course scored the most favourable average SETL result of any courses taught by the Department of Computer Science.

Analysis of the SETL results for this course show that student most strongly agree with the following statements:

- ¥ The different sections of the unit were well integrated
- ¥ The practical project was a useful learning experience
- ¥ The group project was a good learning experience
- ¥ In this unit I was encouraged to think
- ¥ I have learned to make connections between this unit and others
- ¥ I have developed a better understanding of client issues
- ¥ The unit stimulated my interest in the subject

Some of the comments received by students as part of this SETL evaluation are:

> Educationally, we achieved a lot; ... The experience of communicating at a professional level with peers and superiors, across many actual or perceived barriers is not one that can be taught; this and many other types of 'incidental' learning make up at least half of the benefit gained from doing this unit.
>
> Although the workload was higher than in some other units. this project has been an enjoyable experience and will be very valuable in my future working environment.
>
> The unit was really good in making us use the skills and theory we had learnt and forgotten over the last three years. There is a great difference between knowing how to do something and actually doing it. I would recommend the unit to anyone, even though it required hard work and was at times frustrating, overall it was a worthwhile unit and I am glad I did it. I actually enjoyed the project.
>
> This has been the most enjoyable and useful unit I have done in my three years as an undergraduate.

10. Conclusions

The team-of-teams approach adopted in this IT Project course has proven to be a very useful structure through which students have learned a great deal about teamwork, practical project management, and sharing information, as well as completing the technical requirements of the project.

The students rapidly appreciate that apparently simple tasks can become very complex. The initial optimism is tempered by the reality of the tasks they must complete. However, commitment to high quality output has been evident in all projects teams.

It has been evident from the comments received and output achieved in these projects that students have gained a very real appreciation of each of the major human-oriented aspects of software development projects given by Lai[7].

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