# TRIPLE-OBJECTIVE TEAM MENTORING: ACHIEVING LEARNING OBJECTIVES WITH CHEMICAL ENGINEERING STUDENTS

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**Abstract:** A sophisticated style of mentoring has been found to be essential to support engineering student teams undertaking technically demanding, real-world problems as part of a Project-Centred Curriculum (PCC) at The University of Queensland. The term 'triple-objective' mentoring was coined to define mentoring that addresses not only the student's technical goal achievement but also their time and team management. This is achieved through a number of formal mentor meetings that are informed by a confidential instrument which requires students to individually reflect on team processes prior to the meeting, and a checklist of technical requirements against which the interim student team progress and achievements are assessed. Triple-objective mentoring requires significant time input and coordination by the academic but has been shown to ensure effective student team work and learning undiminished by team dysfunction. Student feedback shows they value the process and agree that the tools developed to support the process are effective in developing and assessing team work and skills with average scores mostly above 3 on a four-point scale.

**Keywords:** team mentoring; student teams; team dysfunction.

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## INTRODUCTION

The Project Centred Curriculum (PCC) developed for chemical engineering students at The University of Queensland (UQ) addresses some of the educational challenges arising from various national and international reviews and surveys (IEAust, 1996; World Chemical Engineering Council, 2004; ABET, 1997; IChemE, 2001) by requiring that students work on simulated engineering projects in teams.[1] PCC integrates technical and personal development learning outcomes and skills acquisition, and mandates a significant component of active and cooperative learning i.e., learning by doing—with others. Development of generic graduate attributes such as communication, team work, and project management is contextualized in the technically demanding team project courses where students find these more meaningful and are more likely therefore to engage (Crosthwaite *et al.*, 2001).

The use of student teams in PCC is successful: students are more confident, more able to apply engineering competencies, solve problems working from first principles, and work in teams and on realistic industrial projects (Crosthwaite *et al.*, 2006). However, this result does not arise simply from ensuring that projects are purposefully selected to fulfil a detailed set of learning objectives. Instruction and support tailored to enable the achievement of all the desired learning outcomes must also be provided. It is well recognized that many students leave university deficient in teamwork and leadership skills (Spinks *et al.*, 2006; World Chemical Engineering Council, 2004). Furthermore Johnson and Johnson (1999) remind us:

> Students do not come to school with the social skills they need to collaborate effectively with others. So teachers need to teach the appropriate communication, leadership, trust, decision making, and conflict management skills to students to provide the motivation to use these skills in order for groups to function effectively.

Acquiring proficiency in generic skills, such as team working and time management, requires the students to do more than attend technical key-note lectures and hands-on workshops (Jones, 1996; Smith, 1996). Student teams

[1] Pimmel (2003) uses 'group' and 'team' respectively to indicate the difference between individuals working independently on the same task and individuals working inter-dependently on the same task respectively. This nomenclature is adopted in this paper.

must be allowed to participate in a team that may have a level of dysfunction, and then devise and implement a corrective action. In other words, generic skill acquisition requires a level of experiential learning (Moy, 1999). For example, a student who does not experience a measure of failure due to some form of team dysfunction and who is not then prompted to identify the problem, reflect upon the cause and formulate, trial and assess a strategy for moving forward cannot be said to have mastered the skill of team working (Foyle, 1995; Drake *et al.*, 2006). On the other hand, a student who spends all semester managing a dysfunctional team without help may not achieve technical learning objectives and thus may fail the course (Courtney and Rouse, 2006). Therefore, a new type of mentoring, distinct from the technical tutoring, industry mentor scheme, year advisors, thesis supervision and student support services already available to chemical engineering students at UQ, is required to provide support for the student teams in PCC. It needs to allow inexperienced team workers to 'fail safely' such that team working skills acquisition is maximised but without compromising realisation of technical learning objectives.

'Triple-objective' mentoring was developed as a response to this. It aims to proactively advise and counsel student teams with respect to technical, time and team management issues and to identify and remediate any team dysfunction before it interferes with students achieving learning objectives but not until after students have a chance to manage it themselves. This form of mentoring also assists with the assessment of team skills and subsequent formative feedback to students. Whilst technical competencies are easily assessed through examinations or assignments and failure to achieve technical competencies rectified by additional tutorials or the student being directed to further practice exercises, it is far more difficult to assess 'soft' skills and therefore to overcome any identified deficiencies in student competencies (Clayton *et al.*, 2003). To both assess and address deficiencies, requires the academic to engage with the student and the student team at a different level: that of the mentor. Only by addressing the students individually and on a team basis (Courtney and Rouse, 2006), can the academic provide the necessary instruction.

Mentoring, as used in this work, is 'a nurturing process in which a more skilled or experienced person, serving as a role model, teaches, sponsors, encourages, counsels and befriends a less skilled or less professional person for the purpose of promoting the latter's professional and/or personal development' (Anderson and Shannon, 1988). Mentoring undergraduate students has been shown to result in higher achievements as measured by grade point averages, more units completed per semester, and decreasing student attrition (Campbell and Campbell, 1997). Mentoring postgraduate students has been found to positively influence research self-efficacy, both actual and perceived, and increase productivity (Paglis *et al.*, 2006).

Much work has been undertaken on defining the functions of mentoring; specifically psychosocial and career-related mentoring have been recognized (Kram, 1983). Psychosocial mentoring deals with competence, confidence and effectiveness and is achieved through a measure of informal friendship and counselling. Career-related mentoring deals with preparation for a career through challenging assignments, coaching, sponsorship and introduction to the relevant community of practice. Other researchers have proposed situation specific mentoring, such as research mentoring (Paglis *et al.*, 2006). In this paper, Kram's functions are adopted as they adequately describe what is offered by what we have termed 'triple-objective mentoring': enhancement of technical knowledge, time management and team management. Both technical and time management can be seen to fall under career-related mentoring in that they prepare the student for industry, ensuring that core chemical engineering knowledge is learnt, engineering processes for problem definition and solution are adopted, and project management skills are practiced. Mentoring to achieve team management falls under both career-related and psychosocial mentoring: 'soft' skills required by industry such as team working, negotiation and leadership are developed, and student self-efficacy increased in the process.

However, to successfully implement team mentoring which goes beyond technical needs, the mentor needs skills in excess of those conventionally recognized for professional engineers and academics (Murray and Lonne, 2006). They must establish a close relationship with the student team to address challenges such as 'the chasm between theory and practice, vagueness and open-endedness, and performance anxiety' (Ekwaro-osire, 2003) that are embodied in the projects and the required deliverables.

While final year capstone design courses are often an effective vehicle for intensive career-related mentoring, the PCC approach is to introduce and further extend these benefits by introducing and building on these from the early years. Since 2004, triple-objective mentoring has been used for second year core chemical engineering courses at UQ. Prior to this, mentoring within chemical engineering focussed on technical and time issues only. This was problematic as team dysfunction was usually not discovered until it was too late for intervention (Jones, 1996).

This paper therefore presents the model for, and a case study of, this new type of team mentoring (triple-objective mentoring) implemented as part of the ongoing evolution of PCC. The evaluation of the innovation is made from both academic and student viewpoints.

## THE MODEL: TRIPLE-OBJECTIVE MENTORING FOR CORE SECOND YEAR CHEMICAL ENGINEERING COURSES

### The Second Year Chemical Engineering Programme

The standard enrolment for a full time student is four courses per semester with each course allocated a maximum of 5 h of formal class contact time per week over 13 teaching weeks. Team project work accounts for 25% of the curriculum each semester and is the framework around which the entire curriculum is built. A project course typically comprises a maximum of 1 h per week for a keynote lecture, between 2–4 per week for hands-on workshops. Any remaining formal class contact time is allocated for team project work. Towards the end of semester, less time is allocated to lectures and workshops and therefore more time is dedicated to team project work.

The most intensive mentoring is given to students undertaking the core second year courses: CHEE2001 Process Principles (first semester), and CHEE2002 Process Systems Analysis (second semester). These courses are the student's first exposure to chemical engineering as the first year for engineering students at UQ is general. Figure 1 details the learning objectives for both courses and clearly shows the mix of conventional chemical engineering and generic skills targets. A large mentoring input at this stage provides an introduction to the organisational unit, the community of practice, and teaching and learning expectations. It both establishes the foundations of practice

| **CHEE2001** | |
|---|---|
| 1. Analyse any process as a system including defining sensible system boundaries and identifying all input and output streams. | Given a clearly defined problem for a process:<br>Define clear system boundaries for solving the problem<br>Identify input/output streams at system boundary (mass and energy)<br>Make and clearly state engineering assumptions to solve problem<br>Identify system as batch or continuous, steady state or not<br>Draw a flow sheet representing your analysis of the system<br>Advanced: demonstrate skills for an ill-defined/open ended problem |
| 2. Formulate and solve mass and energy balances for process systems with and without reaction | Given a clearly defined problem for a process:<br>Formulate general mass balance and simplify it for your system<br>Use stoichiometric concepts to simplify component mass balances<br>Convert data into consistent sets of units for solving equations<br>Formulate and use the general energy balance and simplify system<br>Find thermodynamic data from tables, etc. to use in energy balances<br>Collate information to solve mass/energy balances systematically<br>Advanced: demonstrate skills for an ill-defined or open ended problem |
| 3. Have improved:<br>(a) ability to manage own study and<br>(b) ability to work effectively in an engineering team | Ability of the student to:<br>Reflect on learning and improve study approaches<br>Work in team to solve complex problem/communicate solution<br>Identify and overcome issues/problems in a team to make the team result better than the sum of the individuals |
| 4. Produce a clearly written engineering communication and effectively sell a case through oral presentation | Ability of the student to:<br>Write in clear, direct and grammatically correct English<br>Analyse audience and communicate appropriately<br>Use good engineering structure for a written report<br>Present engineering data correctly in tables and graphs<br>Show ability to argue a point clearly and logically<br>Give a clear, well prepared oral presentation<br>Evaluate, edit written and oral communication of peers |
| 5. To develop/practice core process engineering skills | As part of understanding concepts (1) and (2), develop a toolbox of engineering skills. Practice in tutorials and homework sheets. |
| **CHEE2002** | |
| 1. Knowledge of scope of professional practice | Describe the scope, overall setting, and professional engineering activities associated with processes and the process industries |
| 2. System analysis | Explain why a process is a system and identify structure within system |
| 3. Input-output analysis | Determine economic potential of a process and identify operational variables that affect the economics at input-output structure level |
| 4. Design goals | Identify and describe the impact of operational, technical, economic, safety and environmental issues on process goals |
| 5. Flowsheeting | a) Explain the techniques used in flowsheeting,<br>b) Analyse structure and material and energy balance for process,<br>c) Determine DOF for process and when solution is possible,<br>d) Analyse independence and consistencies of process specifications,<br>e) Determine suitable decomposition and tear structures to solve for material and energy balances for processes with recycles |
| 6. Simulation | Simulate and critically interpret a sizeable process flowsheet using the Aspen plus simulator and other appropriate packages including Matlab |
| 7. Unit operations and processes | List key operating and design parameters and equipment selection criteria for a limited set of unit operations and processes |
| 8. Engineering drawings | Incorporate and interpret technical and safety information into a variety of process engineering diagrams using conventional notation and symbols. |
| 9. Team work | Work effectively in an engineering project team |
| 10. Communication | Prepare and present professional standard communications of technical information in written reports, posters, and oral presentations |
| 11. Information skills | Locate, evaluate and use information from a wide variety of sources |
| 12. Personal development | Take responsibility for/manage your work, learning, critical thinking |

*Figure 1.* Learning objectives for CHEE2001 and CHEE2002.

and provides a model for teamwork in third and fourth year courses.

Team projects form 60% of the assessment in CHEE2001 and 100% of the assessment in CHEE2002. Both courses have 'hurdle assessment' that must be passed for the student to receive a passing grade for the overall course. This assessment takes the form of quizzes designed to test technical content learning; if students have been fully participating in team projects, then these quizzes are easily passed. This hurdle assessment ensures that students with inadequate technical competences cannot pass the course based on their group's project grades. In addition, some of the projects are structured such that individuals or pairs within the team undertake separate tasks, and receive individual marks for these sections. For example, a commodity chemical can usually be produced by a number of different processes and this allows individuals to model and analyse different processes (attracting an individual mark) whereas the pooled results are used by the team to select and specify an optimum process for a number of given constraints (attracting a team mark).

The semester 1 project course (CHEE2001) introduces methodologies for successful teamwork as well as introducing students to chemical engineering at UQ. The triple-objective mentoring in this course is very much psychosocial; it establishes relationships between academics and students and introduces them to a model of peer assessment of team work supported by academic mentoring. The projects in this course are smaller than those in the following semester 2 course (CHEE2002), and require 3–4 weeks to complete with intermediate deliverables to ensure time is managed effectively as well as to provide formative feedback. These projects are given to the students in a consecutive manner (i.e., project 2 is introduced after project 1 has been submitted).

The assessment for the semester 2 course comprises two team projects (assignments) concerned with process system analysis. Both are given to the student teams at the beginning of semester. They run concurrently across the 13-week semester thus requiring students to undertake more significant time management. To support this process, the students are, at the beginning of semester, given milestone checklists for intermediate deliverables. The submission date for each of these coincides with a formal mentor meeting which they are required to attend. Figure 2 is an example of such a check list.

Individualized student marks for the team sections of both courses are awarded and calculated by using a peer assessment factor (PAF) which scales the team mark relative to the student's input to the project. With each project's final submission, the students complete a confidential form that rates themselves and the other members of their team by dividing 100 points on the basis of input to the project. The PAF is the sum total of all points assigned to each individual divided by 100. For example, in a team of five, if a student is perceived as putting in an equitable amount of work, each of the team members, including themself, will award them 20 points. The total sum will be 100 ($5 \times 20$) and division by 100 will give unity (1.0). Therefore, a student who contributes an equal amount of work to the project will get a PAF of 1.0 and receive the team project mark. Similarly, a student who puts in extra work, or takes the leadership role, may end up with a PAF of 1.1 and thereby earn a 10% bonus, and a student who fails to engage in the project or put in an equitable amount of work will receive a PAF less than 1.0 and thus their final mark will reflect this low input.

## Triple-Objective Mentoring—the Process

At the beginning of semester, Chemical Engineering academics are assigned as mentors to the project teams comprising four to six students. The teams have a number of formal mentor meetings scheduled throughout the semester with this academic mentor. Student teams also undertake weekly tutorials/workshops together, thus facilitating cooperative learning for the individual (Springer *et al.*, 1999) and allowing the necessary relationship (Edwards and Gordon, 2006) to be developed between the team and the mentor.

There are usually three formal mentor meetings throughout each semester, however the mentor or student team can request further meetings or follow-up meetings should this be necessary. Mentor meetings may last anywhere from 20 min to 1 h depending on the needs of the student team.

Prior to each mentor meeting, the students submit a document in which they reflect on, and evaluate the interim performance of, the team as whole and the individual team member's contribution to this performance (Figure 3). This document is confidential in that only academics have access to the student's thoughts; therefore students are more able and likely to express concerns and conflicts. PAF scores calculated from this document are used by the mentor for formative feedback purposes. The document therefore serves the dual purpose of forcing the students cognitively to recognise the manner in which the team and individuals are performing (Drake *et al.*, 2006) and of allowing the mentor an insight into the team's operation.

This insight allows the mentor to initiate a discussion of any identified team dysfunction during the mentor meeting with the aim of leading the team to formulate strategies for future work. These strategies may comprise methods for improved technical competence, better time management, increased team/individual performance or better communication.

A mix of discussion of technical, time and team issues within the mentor meetings is important to engage the students and to ensure improvement. A meeting to discuss team function alone is not valued by the students and on their part very little engagement occurs if this is its only purpose. Providing advice on summative assessment or advice on how to increase the team's performance on the next piece of summative assessment ensures that the students engage and the meeting is therefore more productive.

This formalized system of mentoring student teams has been developed over the past 6 years with some improvements being introduced as a result of student feedback. For instance, student reflection on team performance was originally made on a team basis; this was changed to individual reflection when it was realized that students could not be truly reflective if they felt that they were going to make enemies of friends and people that they have to work with for another two years (Murray and Lonne, 2006).

## Mentor Skills

In both second year projects courses, five to six groups are allocated to each academic mentor. Mentoring this number of

**CHEE2002 Process Systems Analysis**
**Review meeting 3**

Mentor……………………

Team………………………

Any students not present……………………………………………..
Reason…………………………………………………………………

Team meeting logs records presented for inspection……………………………

Project 1.

Linked Simulation working…………………………………………..
Sections 3 - 5 complete and in final report form……………………..
Does the team have any concerns with this report section?…………

Tasks yet to be completed are?.........................................................
Any likely problems for on-time completion?...................................
Who is doing the final compilation?................................................
Who is doing the editing/proof reading?..........................................

Are there any peer evaluation issues for Project 1?…………………
……………………………………………………………………..

Project 2
Section 1 complete and in final report form…………………………
Does the team have any concerns with this report section?…………

Section 2 complete and in final report form…………………………
Does the team have any concerns with this report section?…………

Section 3 Unit process for study identified…………………………
Process chemistry identified…………………………………………
Major equipment and features identified……………………………..

Section 4 Unit operation for study identified…………………………
Essential physics identified…………………………………………...
Major equipment and features identified……………………………..
Design data requirements and procedures identified…………………

Section 5 Case study completed and draft available…………………

Information for inclusion on poster identified…………………………
Draft poster layout prepared…………………………………………..

*Figure 2.* Example of CHEE2002 mentor meeting checklist.

## INDIVIDUAL REVIEW - MENTOR MEETING 1

**NAME:**______________________**TEAM:**______________**DATE:**_____________

1. Please circle the rating that best describes your team for each of the three items below:

a. How productive was the group overall?

| | | | |
|---|---|---|---|
| accomplished some but not all of the project's requirements | met the project requirements but could have done much better | efficiently accomplished goals that we set for ourselves | went way beyond what we had to do exceeding even our own goals |

b. Which of the following best describes the level of conflict at group meetings?

| | | | |
|---|---|---|---|
| no conflict, everyone seemed to agree on what to do | there were disagreements, but they were easily resolved | disagreements were resolved with considerable difficulty | open warfare: still unresolved |

2. Please rate yourself and each team member on the following
(1 Disagree, 2 Tend to disagree, 3 Tend to agree, 4 Agree)

| **Team member's name** | **SELF** | | | | |
|---|---|---|---|---|---|
| Took a leadership role | | | | | |
| Helped team overcome differences | | | | | |
| Fully engaged in discussions during meetings | | | | | |
| Often excessively dominated team discussions | | | | | |
| Contributed useful ideas | | | | | |
| Kept open mind/ willing to consider other ideas | | | | | |
| Encouraged team to complete project on time | | | | | |
| Delivered work when promised/ needed | | | | | |
| Had difficulty negotiating with team members | | | | | |
| | | | | | |
| **Distribute 100 points for overall contribution to the team's effort (include work, communication, problem solving etc.)** | | | | | |

3. Please review items 1. and 2. and write a brief description of any problems or conflicts you encountered in working with this group and how they were resolved. (Continue over the page if necessary.)

*Figure 3.* Mentor meeting reflection form (adapted from van Duzer and McMartin, 1997).

teams, whilst onerous in the weeks where mentor meetings are scheduled, has been found to be sustainable provided recognition of the 'lumpiness' of the workload is factored into, and planned for in the academic's semester schedule. The use of on-line tools to assist in the management and documentation of the process is essential.

Team mentoring requires the academic mentor to become less of a problem solver and more of a facilitator (Edwards and Gordon, 2006). This is usually in direct contravention of everyday engineering practice: we are trained to define and solve problems (Spinks *et al.*, 2006). It can be very difficult to sit back and let the student team decide direction, and plan strategies for improving team performance. Academics must take off the project manager hat to become the required listener and counsellor.

There is no one 'right' way to mentor a team and many options to choose from: ". . . it is pertinent for teachers to consider a variety of strategies for monitoring cliques, addressing scapegoating behaviour and encouraging democratic participation." (Courtney and Rouse, 2006).

Our experience has been that different depths of mentoring styles can result in differences of up to 10% in the final marks of students. Teams with mentors who review their team's work prior to the final report submission and give methods of solution, as well as instructions for further work will obviously score well as their submissions are targeted towards assessment criteria. The teams of mentors who choose to make the students research solutions and arrive at decisions/directions based on a discussion of the available options tend not to do so well in terms of final marks but perhaps are set more firmly on the path to lifelong learning (Spinks *et al.*, 2006). To reduce the incidence of final team marks varying with mentor, the project course teaching team now agrees the depth of mentoring to be offered at the beginning of each semester. There is however a great temptation to be liked in teaching which can lead mentors into sub-optimal behaviour and we have found that agreement of the model for mentoring with the teaching team does not necessarily ensure that all mentors will follow the chosen model.

The mentoring literature (e.g., Edwards and Gordon, 2006; Paglis *et al.*, 2006) suggests that the success of mentoring depends as much on the relationship between the parties as any particular process. We have found that the depth of mentoring offered should be based on the maturity and nature of the cohort and the learning objectives. The following models are offered:

- 'Mentor as Mother'—The mentor leads the team's discussions, ensures tasks are being completed to the required standard, directs the team to information that the team may have overlooked, and reviews work before it is submitted for grading. (Note that this may be problematic as it can lead to the aforementioned anomaly in final marks and has potential to signal unintended support for a culture of working for marks rather than working for learning.)
- 'Mentor as Devil's Advocate'—The mentor is integral to the team discussions and acts to bring the team's focus to aspects that require resolution. They will not necessarily offer direct answers but rather encourage the team to arrive at a correct solution themselves. Aspects that the team has not considered will also be raised by the mentor.
- 'Mentor as Expert Witness'—The team directs all meetings; only subjects raised by the team are discussed. The mentor answers questions directly, and does not raise uncertainty.
- 'Mentor as Polymorph'—The mentor takes on any of the above roles as required by the team, situation, and/or learning objectives.

These models represent extremes and there will be a number of other intermediate models. However, it is important that the mentor does not become part of the team as this would undermine student learning due to the overlay of additional and necessarily different goals that the mentor would impose on the shared vision of the team, its priorities, activities, and targets. Table 1 attempts to quantify the depth of mentoring offered by each of the three models.

Workshops for academics, project leaders, and tutors undertaking the role of student team mentor raise the issues discussed above and allow the potential mentors to discuss the requirements for triple-objective mentoring. The workshops employ role play scenarios with real data from student teams and give these mentors an introduction to possible strategies.

### Assessing Triple-Objective Mentoring

In 2004, five student teams in the Process Systems Analysis course (CHEE2002) were monitored closely to evaluate in depth the effectiveness of triple-objective mentoring in supporting team work and to gain detailed feedback from the students. Two of these teams were interviewed on completion of the course to determine the value of triple-objective mentoring and what improvements, if any, were necessary. The entire cohort was also surveyed using a questionnaire asking them to rate the specific elements of the mentoring system and to give feedback via open-ended questions.

In this cohort there were 15 student teams with an average of six members. Three academic mentors were each assigned five teams.

## TRIPLE-OBJECTIVE MENTORING—A CASE STUDY

'I think the best thing in this course would be the mentor meetings and team collaboration by mentors to stop teams crashing and to encourage potential "free riders" to get in and contribute. The methods for this "team monitoring" I feel should be expanded and applied to every course in engineering (and even the university) which has predominantly team work based assessment' (CHEE2002 student, 2004).

### The Occurrence of Team Dysfunction

Before the introduction of triple-objective mentoring, when mentoring was purely technical in nature, approximately two out of every five student teams experienced some sort of dysfunction. This ranged from scenarios which would cause them a level of angst and a few 'all-nighters' to finish work that had not been completed due to a team problem, to the most extreme that would cause them to fail the course. As an example, prior to the introduction of triple-objective mentoring, one CHEE2002 student team with five intelligent and articulate male students failed to submit a cohesive process

*Table 1.* Mentoring models.

| Aspect | Level 1: Mentor as mother | Level 2: Mentor as devil's advocate | Level 3: Mentor as expert witness |
|---|---|---|---|
| Meetings: | | | |
| • Structure | Set by mentor | Mentor agrees with team | Set by team |
| • Chair | Mentor | Team member supported by mentor | Team member |
| Technical details | | | |
| • Missing information | Mentor supplies | Mentor leads discussions such that team discovers omission (or not) | No input by mentor unless asked directly |
| • Incorrect information | Mentor identifies, corrects and explains | Mentor discusses methodology and possible solution with team | No input by mentor unless asked directly |
| • Review of work | Mentor reviews work before submission | Mentor reviews only as requested by students | No review |
| • Decisions | Mentor indicates best way to solution | Mentor discusses various options; team decides | No decisions made by mentor but opinions can be given if asked for |
| Team management | | | |
| Team performance/ conflict resolution | Mentor to ensure team performing to best of ability by setting strategy for future work | Mentor raises issues and encourages team to devise strategy for improving performance | Mentor must ensure team is functional but aims to minimise intervention |
| Social loafing (see note) | Mentor to talk to team and social loafer to ensure rehabilitation | Mentor brings up issue and lets team decide how to move forward | Mentor must ensure that the issue is raised. A greater level of intervention may be required. |
| Time management | Mentor to ensure that team is on time and will complete work | Mentor raises critical path issues but leaves team to decide time management | No input by mentor unless asked directly |

*Note:* 'Social loafing is the tendency for individuals to expend less effort when working collectively than when working individually' (Karau and Williams, 1993). In our experience it can cause extreme team dysfunction resulting in poor student learning and satisfaction.

system model for Project 1 and failed to get a poster to the poster presentation session arranged for Project 2. Four of these students received a conceded pass for the course and one, student X, a failing grade. Individual students within the team were approached to explain the team failure. It transpired that student X had not submitted promised work throughout the semester, always promising to make amends the following week. The rest of the team managed to cover for him throughout most of the semester but the final non-submission meant that their deliverables were incomplete and late. Outcomes such as the sensitivity analyses which can only be undertaken once a cohesive process system model is established, had not been achieved and a high level of anxiety was evident: 'If I never have to work with <student X> again it will be too soon' (CHEE2002 student, 2003).

This situation could have been avoided if mentoring of team function had been provided throughout semester with the students allowed individually and confidentially to reflect on the team's progress and individual efforts. The poor performance of student X could have been revealed in the first third of the semester and mentoring/monitoring employed to rehabilitate the student and to ensure the other students in the team still managed to achieve required learning objectives.

Since the introduction of triple-objective mentoring, no teams in CHEE2001 and CHEE2002 have failed due to social loafing or inter-personal conflict, another dysfunction which previously caused teams to fail as a whole. The failures are now individuals, such as student X, who do not undertake the work necessary to achieve the required technical content learning and fail to pass the hurdle assessment and/or are penalized by the PAF system of assigning individual marks. Their non-completion now no longer affects the team as alternative and timely strategies are put in place by the mentor and the team. For example, there were two students who failed CHEE2002 in 2005. Both were social loafers who did not contribute equitably to the projects; they were identified early and received cautions from their mentors and teams to no avail. However, the other students in their teams did not fail and were able to demonstrate complete and successful achievement of learning objectives through passing hurdle assessment, acceptable quality of final submission, and PAFs close to or better than unity. The strategies developed with these students meant that their learning was not negatively impacted by the social loafer.

In most cases, social loafers identified early in the project are able to be rehabilitated and become highly valued members of the team, once they have been made aware of their unacceptable behaviour. The reasons for social loafing have been found to be many and diverse including: outside work pressure, lack of confidence, a difference in goals, and a different style of working. Most of these reasons can be addressed successfully with respect to team work and achieving and assessing learning.

A further team dysfunction is the 'non-team player'. In a cohort of approximately 100 chemical engineering students there are usually one or two students every year that fit this category. These students are often highly intelligent and motivated but do not like team work. They usually do not agree with the methodology, standard, or outcomes of their team and hence develop their own model/report for separate submission. These submissions are usually of high distinction (>85%) standard and hence the students are able to demonstrate achievement of the course technical learning objectives although not the team skills. Mentoring in this case is just as necessary as with the social loafer team, as the Spresence of the non-team player can affect the morale and output of the rest of the team. Triple-objective mentoring has enabled us to identify these students early in semester and work actively with them in an attempt to increase their team working skills and support the rest of their team.

## A Study of Five Teams

The following section outlines the outcomes for the five CHEE2002 teams (A–E) which were monitored in detail to explore the impacts of triple objective mentoring.

Table 2 shows the peer assessment scores achieved by each individual in each of the five teams. Team E was the only team that required no team facilitation during mentor meetings and this is reflected by their PAFs which show that the work is equitably undertaken by all members; instead their mentor meetings focussed on project management and technical queries. It should be noted that a PAF of 0.9 is usually not indicative of social loafing but rather a result of students rewarding other members of the team; to do this they have to take marks from another student.

Teams B, C and D all contained students who received a score less than 0.9 but greater than 0.7 or who were mentioned in comments in individual reflections by their team mates as not pulling their weight prior to the second meeting of the semester.

> Some members have apparently done a lot of research and information gathering but so far haven't contributed anything material and seem to have no inclination on doing anything above what is required (Student C1, Team C, Review Meeting 2).

These students were not named in the subsequent mentor meeting but a discussion of the fact that there were members of the team judged to be not pulling their weight was initiated. The teams were asked if they wished to discuss this with the mentor or whether they would prefer to address it themselves. In all cases, the team decided to sort out the social loafing problem without help from a mentor; the mentor was needed only as a devil's advocate. The peer marks for the assignments show that this intervention and the following team discussions were successful in rehabilitating the loafing team member.

> B3 has started to pull his weight after last review meeting (Student B4, Team B, Review Meeting 3).

> The last meeting made clear that some people weren't putting in what was required and are now seeking to rectify that (Student C1, Team C, Review Meeting 3).

Team A had a larger problem with two students who had very low PAF scores. These students were named in the subsequent mentor meeting; it was made clear to them that the team did not wish for their expulsion but rather wished them to complete their fair share of the work. One of the named students reacted negatively to this intervention at first but both students managed to become active participants of the team through continued mentoring and team discussion.

*Table 2.* Peer assessment scores.

| | | PAF | | | | |
|---|---|---|---|---|---|---|
| Team | Individual | Meeting 1 | Meeting 2 | Meeting 3 | Project 1 | Project 2 |
| A | A1 | 1.0 | 0.9 | 0.9 | 0.9 | 0.9 |
| | A2 | 1.0 | 0.8 | 0.9 | 1.0 | 1.1 |
| | A3 | 1.0 | 1.0 | 1.1 | 1.2 | 1.2 |
| | A4 | 1.0 | 1.2 | 1.3 | 1.2 | 1.2 |
| | A5 | 1.1 | 1.2 | 0.9 | 0.9 | 0.8 |
| | A6 | 0.0 Note | 0.7 | 0.9 | 0.9 | 0.9 |
| B | B1 | 1.1 | 1.2 | 1.1 | 1.1 | 1.1 |
| | B2 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 |
| | B3 | 1.0 | 0.7 | 0.9 | 1.0 | 0.9 |
| | B4 | 1.0 | 1.1 | 1.0 | 1.0 | 1.1 |
| | B5 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 |
| C | C1 | 0.9 | 1.3 | 1.1 | 1.0 | 1.0 |
| | C2 | 1.1 | 1.2 | 1.1 | 1.1 | 1.2 |
| | C3 | 1.0 | 1.2 | 1.1 | 1.1 | 1.2 |
| | C4 | 1.0 | 0.9 | 0.9 | 0.9 | 1.0 |
| | C5 | 1.1 | 0.8 | 0.9 | 0.9 | 0.9 |
| | C6 | 1.0 | 0.9 | 1.0 | 1.0 | 0.9 |
| D | D1 | 1.2 | 1.2 | 1.1 | 1.1 | 1.0 |
| | D2 | 1.1 | 1.1 | 1.0 | 0.9 | 0.8 |
| | D3 | 1.3 | 1.0 | 1.0 | 1.0 | 1.1 |
| | D4 | 0.9 | 1.1 | 1.0 | 1.0 | 1.0 |
| | D5 | 0.9 | 0.9 | 1.0 | 1.0 | 1.0 |
| | D6 | 0.8 | 0.9 | 1.0 | 0.9 | 1.1 |
| E | E1 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 |
| | E2 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 |
| | E3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 |
| | E4 | 1.1 | 1.0 | 1.0 | 0.9 | 1.0 |
| | E5 | 1.1 | 1.1 | 1.0 | 1.1 | 1.1 |
| | E6 | 0.9 | 1.0 | 1.0 | 0.9 | 0.9 |

*Note:* Student A6 did not attend lectures until week 4 and hence was not thought to be part of the team.

The other scores of note belong to student A5 of Team A and student D2 in Team D who both achieved a score of 0.8 for the final assignment. Student A5 is somewhat of a mystery as they had previously shown no sign of social loafing but effectively dropped out of the team in the final two weeks of semester. E-mails and SMS text messages were not returned. This student also failed to attend the final team review meeting. Discussion with the team indicated that the student may have had personal problems or that conflict with another member of the team may have finally become insurmountable.

> Some conflict was evident between A5 and myself. I tried to be diplomatic but it is still unresolved. Been pushed aside (Student A2, Team A, Review Meeting 3).

The conflict was evident through mentor meeting reflection and evaluation forms and was found to be difficult to remediate within the scope of a chemical engineering course; both authors felt that student A2 was slightly unstable based on personal interaction with them. The problem was mentioned during the mentor meeting as something that was occurring within the group and the team put forward a strategy to overcome the conflict. The success of this strategy or otherwise was never confirmed as student A5 was not available for interview.

The experience gained from this incident has been invaluable however. In 2006 and 2007, students were successfully reassigned to different teams when conflict was identified by the mentor and judged by the mentor and teaching team to be irreconcilable to the point of negatively impacting on the student's learning. In hindsight this is perhaps what should have happened for Team A but at the time it was felt that the individuals within the team could work out their differences.

Student D2 of Team D is an English as a Second Language (ESL) student. The second assignment was a research and writing project and the team thought that D2's language skills were not up to the required standard and therefore did not utilize D2 heavily. D2 therefore received a low mark not through social loafing but through inability to take on an equal share of the significant amount of written work in the second project. Whilst there is a minimum language standard for ESL students at UQ, some are unable to deliver on the team's required standards and quality of written and oral reporting. This issue is not discussed here other than to say that those ESL students with high technical competency but poorer English skills can become valued team members but those with average technical competency are often marginalized (Springer *et al.*, 1999) as was the case with D2. In our experience, in cases such as this, mentoring can raise the standard of support for the ESL student within the team but usually fails to bring final peer assessment to unity.

Two of the five teams were asked to participate in a final debriefing discussion and reflection group interview of 30 min duration. The teams were hand picked; the first for continuous team success and a high degree of team cohesiveness from the beginning of semester (Team E) and the second for overcoming the hurdle of two social loafers (Team A). Both teams were willing and active participants in the additional meeting.

The teams felt that, although one of their first tasks as a team was to construct a Gantt chart for project management purposes, the mentor meetings were essential in terms of confirming what (technical) should be done by when (time). They indicated a lack of confidence in their initial plans as they felt inexperienced in estimating the length of time for a particular task and felt that the checklist for each mentor meeting gave much needed advice.

The mentor intervention with Team A, whereby the two members identified as not pulling their weight by the rest of the team were named (A2 and A6), was discussed. The team, including the named members, agreed that the intervention had been justified and successful; it had turned A2 and A6 into valued team members. The result of such an intervention was agreed to have facilitated an immediate rehabilitation whereas it was thought a gentler intervention probably would not have had this effect. Table 3 summarizes the conclusions drawn from these meetings.

*Table 3.* Final group meeting conclusions.

| | Team E | Team A |
|---|---|---|
| Description | Successful | Social loafer problem |
| Final outcomes | • Winner of poster prize<br>• High quality final deliverables (distinction: 75–85% and high distinction: >85%) | • Short-listed for poster prize<br>• Good quality final deliverables (credit: 65–75% and distinction: 75–85%) |
| Hurdles | None | • One member missing for first 4 weeks<br>• Inefficient leader nominated in first week for first project<br>• Two members named as social loafers (week 7)<br>• Conflict between one student and two other team members<br>• Member 'dropped out' after week 11 mentor meeting |
| Reasons for success | • Good communication—team set up group email<br>• Group ownership of all tasks<br>• Immediate response to queries/ requests for help<br>• Good mix of skills/roles within group | • Very strong leader who sorted out task and people problems<br>• Leader had respect of all team and used this to resolve conflicts<br>• Rapid turn around of week 7 social loafers after mentor intervention |

Both teams also reported that they appreciated and enjoyed the extra 30 min meeting and suggested that this opportunity for feedback be given to all groups in future years.

## Feedback from the Cohort

> Very helpful, partly helped keep us in track. This is because I believe that our group would have survived regardless but I know PERSONALLY I found the whole thing very helpful (CHEE2002 student, 2004).
>
> . . . I believe that it helped a lot in my team work skills and organization. And it would be great for this to continue (CHEE2002 student, 2004).

The questionnaire given to CHEE2002 students in 2004 asked each student to rank each section of the triple-objective mentoring from 1 (no use) to 4 (essential). Table 4 details the average class scores for each of the questionnaire sections. Analysis of the answers on a team basis showed that there were two teams (Team F and Team G) who were significantly more dissatisfied with the intervention and also two teams (Team E and Team H) were significantly happier with the intervention than the overall class. These scores are also reported in Table 4 to indicate the class spread of opinion.

Overall, the triple-objective mentoring was a success with average class scores ranging from 2.6 to 3.8. In particular the mentor meetings and the checklist for mentor meetings appear to have been very well received.

With respect to teams E, F, G and H, discussions with team mentors did not show any particular reasons why they should have significantly different perceptions of triple-objective mentoring to the rest of the cohort. However, it was recognised that the 'positive' teams had good systems of communication in place and were highly successful in all facets of the course. Although one of the 'negative' teams had a problem with a social loafer who was never present due to work commitments and the other appeared to have trouble with organizing meetings which all team members could attend, both teams appeared to have no problems in terms of their technical content learning.

The quantitative results of the questionnaire validate the use and effectiveness of triple-objective mentoring and this is supported by the responses to the open-ended questions:

- On the assessment forms
  - *Imperative in keeping the team members on track and serve as a check and balance on whether everyone has pulled their weight or not.*
  - *Forms were good to allow problem team members to become identified and to allow for fair marking.*
  - *The individual team review for mentor meeting and checklist for mentor meetings were by far the most useful group work tools I have ever used.*

*Table 4.* Student questionnaire results.

| Assessment forms – overall (1 no use, 2 some use, 3 useful, 4 essential) | | | | | |
|---|---|---|---|---|---|
| | Class | Team F | Team G | Team E | Team H |
| Individual team review for mentor meetings | 2.9 | 3.2 | (2.2) | 3.2 | 3.5 |
| Checklist for mentor meeting | 3.8 | 3.8 | [3.2] | 4.0+ | 3.7 |
| Anonymous individual assessment submitted with submission of team project | 3.2 | 3.2 | (2.6) | 3.2 | 3.3 |
| **Mentor meetings – timing (1 wrongly timed, 2 little use, 3 some use, 4 perfect)** | | | | | |
| | Class | Team F | Team G | Team E | Team H |
| Meeting 1 | 2.8 | 2.6 | 2.6 | 3.5+ | 3.3 |
| Meeting 2 | 3.6 | 3.8 | (3.0) | 3.8 | 3.7 |
| Meeting 3 | 3.6 | 3.8 | (3.0) | 3.7 | 4.0+ |
| **Mentor meetings – information (1 no use, 2 little use, 3 useful, 4 essential)** | | | | | |
| | Class | Team F | Team G | Team E | Team H |
| Technical input from mentors | 3.5 | 3.8 | 3.2 | 3.7 | 3.7 |
| Time management input from mentors | 3.1 | 3.0 | [2.4] | 3.3 | 3.7 |
| Team facilitation input from mentors | 3.2 | 3.0 | 2.8 | 3.2 | 3.7+ |
| **Individual review form – sections (1 no use, 2 little use, 3 useful, 4 essential)** | | | | | |
| | Class | Team F | Team G | Team E | Team H |
| Reflection on my team and the team process | 3.1 | [1.8] | (2.6) | 3.2 | 3.3 |
| Reflection on individual's performance | 2.6 | 2.6 | (2.0) | 3.0+ | 3.0+ |
| Scoring individuals out of 100 | 2.7 | 2.6 | 2.4 | 2.7 | 3.0 |
| Comments on sections 1 and 2 | 2.7 | 1.2 | (2.0) | 3.2 | 3.0 |

*Notes:* 1. Values in square brackets, [ ], are greater than one standard deviation below the class average. Values in round brackets, ( ), are the lowest average achieved by a team but are within one standard deviation of the class mean. 2. Values followed by an asterisk, *, are greater than one standard deviation above the class average. Values followed by a plus sign, +, are the highest average achieved by a team but are within one standard deviation of the class mean.

- On mentor meetings
  - *The mentor meetings are a must do for future years and if possible every team work based course.*
  - *They helped our group pull together at some difficult times. Made some of the group pull their weight*.
  - *. . . Sometimes refocused our group to get things done and to what extent.*
  - *. . . by interacting with students, [mentors gave] insights which normally would not be gained from staff.*
  - *Any input from tutors helped improve group facilitation to an even higher level. Same with technical and time management.*

In addition, the majority of students indicated that an initial mentor meeting wherein course requirements were discussed would be useful and, as previously mentioned, the two teams who were debriefed thought that the opportunity to reflect with the mentor on strengths and weaknesses of their team should be offered to all teams.

Approximately half of the comments were negative, although some of these negative comments contained constructive suggestions:

- On the assessment forms
  - *Too much.*
  - *Can't really say what they were, so they obviously weren't very useful to me.*
- On mentor meetings
  - *The meetings were very intense and no one was relaxed attending them.*
  - *The mentor repeatedly asking if there were any intergroup issues made me a bit paranoid about some other group member. Thoughts like "are they complaining about me behind my back", "Does someone have an issue with me".*
  - *Mentor meeting seemed to be turned into a chance to promote themselves for individuals . . . this lead to tension between the group.*

Some of the negative comments on the mentor meetings were seen to be a direct result of different mentor styles and the inexperience of the particular academic undertaking the role.

## CONCLUSIONS

Project-based learning and its many variations are increasingly being used around the world by engineering educators to deliver learning and experiences through student team work on large industrial projects. However, adopting this method of teaching requires that consideration be given to the type of student instruction and advising offered: the staff commitment to the student project teams needs to be larger and the skills required are quite different to those required for traditional instruction. The role of the mentor needs to be defined in terms of the learning objectives of the class and the roles need to be codified to get more consistent mentoring across courses.

'Triple-objective' team mentoring, which is used to support the Project Centred Curriculum at UQ, requires significant input of time, planning, and coordination from academics and a readjustment of the academic's expectations of what is normal in terms of the time required to 'teach' into the course. Significant efforts are also required in terms of staff training to ensure successful implementation of this approach. However its introduction to the second year project courses has meant that the achievement of effective student team work and learning in the second year of the chemical engineering degree is not diminished by team dysfunction. The students are better prepared for managing their own teams in later years of study when they undertake further team work on increasingly larger, more complex and open-ended projects, and eventually for professional practice. Reports from and regarding the first cohort to experience triple-objective mentoring, who are now in their final year of study, attest to the effectiveness of this approach in building both their confidence and abilities in team work.

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Queries

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No Queries