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Student Peer Assessment: A research study in a level III core course of the bachelor chemical engineering program

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ABSTRACT

A study of anonymous student peer marking in a level III (third year) core course of the bachelor chemical engineering has shown that there was no significant difference ($p > 0.05$) in the average marks awarded by student assessors who had idealized solutions of the lecturer compared with those who did not; although more students with solutions (84%) completed the peer task than those without (69%). Students in a cohort of 64 (21 females, 43 males) were randomly assigned as a student-pair and tasked to mark each other's solutions to three numeric-type problems out of a possible 50, but only one student had idealized solutions. In 49 valid responses, 27 with and 22 without solutions, the maximum mark awarded by any assessor was 49 and the maximum awarded by the tutor was 50. The overall mean grade over the three problems was 14.3 for those with solutions and 14.5 without. The overall mean grade of the experienced tutor was 14.6. Despite this agreement in mean marking there were notable differences between student assessors and tutor marks in particular cases. The problems required stage calculations with reflux and column efficiencies; each had the marks indicated to be awarded for all sub-sections. Granularity in grades for both student assessors and tutor was a 1/2. There was no evidence of student collusion in marking. Independent survey results showed more than 3/4 of all student assessors highly valued this learning experience and that it stimulated interest in the course material. Students without solutions however were marginally less likely to want to have peer assessment in other courses ($p = 0.095$).

Keywords: Undergraduate peer assessment; Students' marking behaviour; Quantitative students' evaluation; Anonymous peer feedback; Learning and teaching in higher education

1. Introduction

Peer assessment is the process in which students in a course or tutorial group assess the work of other learners in the group (Topping, 1998, 2009). Typically, the students are in the same year of study and have similar, but not necessarily equal, skills. Research in peer assessment has been carried out since the 1920s (Kane and Lawler, 1978); but it appears to have actually been used from the early 1800s (Gaillet, 1992). Peer assessment may be either formative or summative (Newton, 2007; Aboulsoud, 2011; Davis et al., 2002; Orsmond et al., 1996). In higher education, peer assessment is an important component of a lecturer's limited resource pool for giving feedback in a large class (O'Moore and Baldock, 2007; Ballantyne et al., 2002). For the student, peer assessment is a useful tool for reflective learning (Moon, 1999; Boud et al., 1985; Schon, 1991) as it permits comparison of methods of other students with their own work.

In a recent overview of the literature on undergraduate peer assessments Vickerman (2009) found that students regarded the experience as positive for their learning, and provided positive support for its use. Evidence from a number of studies showed close correlations between student and staff grading with little effect from personal biases of the students (Kane and Lawler, 1978); however there was evidence to suggest that the marks provided by students may have different characteristics from those of an experienced marker. This includes students awarding grades in defined ranges, rather than in the

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more continuous nature of grades provided by tutors (Coulson, 2009). Additional benefits to students from peer assessments were reported by Lindblom-Ylänne et al. (2006) such as engaging with tasks beyond the initial deadline for submission and being actively involved in their own learning. According to Topping (2009) peer assessment may also provide cognitive gains. In peer assessments of essays there was evidence that technical aspects are easier for students to grade reliably rather than content (Lindblom-Ylänne et al., 2006). This was also the finding reported by Davey (2011) where postgraduate course-work students graded numeric questions equally on average with the lecturer, but less reliably in descriptive questions. Compared with student self-assessment, peer assessment appears to offer equal validity over all student year levels; whereas self-assessment appears to be less effective in earlier years (Falchikov and Boud, 1989; Falchikov and Goldfinch, 2000). More recently, Willey and Gardner (2009) reported an increase in student learning from peer assessments of group assignments in an undergraduate engineering course.

The mechanism by which learning outcomes are improved via peer assessment is not clear. It is however likely to rely on student engagement with the task, as well as a process of reflection. Also unclear is how much guidance students require to assess the work of others and whether too much detail in the marking scheme may hamper the reflective process for students. According to Orsmond et al. (1996) for peer assessment to be effective the assessment criteria need to be made clear.

In a recent study of postgraduate chemical engineering coursework students (Davey, 2011) the idealized solutions and marking scheme of the lecturer were used by student assessors. The students stated they believed that the solutions of the lecturer were essential to accurate peer grading, and to their obtaining insight into what the lecturer (examiner) was looking for. Anecdotal evidence revealed that peer assessments had not been valued by undergraduate students at the same university because the idealized solutions and marking scheme had not been made available.

Curiously however, there appears no research reported on the effect of providing some students with idealized solutions with which to peer assess.

Against this background a study was undertaken of the effect of some student assessors having the idealized solutions of the lecturer on the same peer-assessed assignments. Students in an undergraduate chemical engineering program were asked to anonymously assess hard copy tutorial work of one randomly assigned anonymous other in a core course in separations processing and to evaluate their experience using a Student Experience of Learning & Teaching (SELT) survey. The purpose was to examine the impact and value of peer assessment as a learning activity for these students, and to assess the effect of providing some students with idealized solutions to assess with.

2. Aims

The aims of the study were to:

1. identify any difference between the marks student assessors give if they have the solutions or not; and
2. determine if students valued this type of active peer assessment learning.

3. Materials and methods

3.1. *Course and cohort*

The course was a 3-unit (nominally 45 h) level III (third year) undergraduate course on separations processing titled *Applications C* (*Separations Processes*) that was delivered in one-semester in the School of Chemical Engineering, The University of Adelaide, Australia. A total of 12-units are attempted in this semester. Separations Processes is a core course in globally accredited chemical engineering programs (Anon., 1989) in which students are introduced to the principles and applications of diffusional separation processes involving gas–liquid, liquid–liquid and solid–liquid systems in equilibrium-stage and continuous-contact operations (e.g. Foust et al., 1980; Geankoplis, 2003; Wankat, 2007).

Course outcomes are that students should be able to calculate the number of stages required for multiple-stage separation operations such as distillation, liquid extraction, leaching and gas absorption and determine the height of continuous contact separators such as packed towers used for gas absorption/desorption and distillation. The course is highly mathematical in content.

The course cohort was a combined class of 71 students. Sixty four (64) were undergraduate Australian (local) students (18 females, 46 males), none of whom were repeating, and seven were postgraduate course-work students from China and South East Asia (5 females, 2 males) undertaking the course as part of foundation studies for a conversion Master of Chemical Engineering. All the students had chemical engineering backgrounds in undergraduate study and had been enrolled for at least one semester.

The course delivery included a significant number of illustrative problems and idealized solutions. The course materials included lectures, tutorials, mid-term test and 3 h written examination (1 h Closed Book, 2 h Open Book) and, additionally for the conversion masters students, a design project and report, an essay and a public presentation (25 min). Emphasis was placed on problem solving and illustrative worked examples with idealized solutions that would later be useful in a wide range of chemical engineering processes.

Because the students overwhelmingly felt they were not in a position as peers to potentially penalize or promote the grades of class mates, the marks awarded by the student peers were not used in the final assessment for this course. The range of student academic ability, based on transcripts of summative results for other courses, was broad.

In initial discussions with the class by the lecturer, students unanimously expressed a high level of enthusiasm to take part in the study. They all stated that they understood what was expected of them and they believed that it would be a very interesting exercise.

3.2. *Human research ethics committee*

Approval for the case study was obtained from the Human Research Ethics Committee, The University of Adelaide, together with the University Survey Approval Committee who look to balance the timing and number of surveys in which students may be requested to participate.

3.3. *Peer assessments*

The assigned work consisted of three numeric-type tutorial problems, used for some time in alternative years in the course by the lecturer. The problems are presented as Appendix A. The marks to be awarded for Problems 8, 9 and 11, are respectively, 20, 15 and 15, giving a total possible out of 50. The problem solutions required a demonstration of the understanding of reflux, calculation of the number of equilibrium stages and the optimum feed plate, and; an understanding of column efficiencies. The problem statements indicated the total marks to be awarded and the marks for each sub-section. The students were expected to fill in finer grading details for themselves (O'Moore and Baldock, 2007). The students submitted their hardcopy solutions by the agreed deadline for date-stamping and grading by the tutor.

Each student was asked to anonymously mark the work of one anonymous peer. Because students had been used to working in study groups of three in their course assessment tasks, assessors were randomly allocated the work of a peer from another study group. In this way student assessors were not marking work of a peer from the same group.

Each student received a Participant's Package. This contained a hardcopy of an Information Sheet, outlining the research study they had agreed to participate in, and a Consent Form that was to be signed (both mandated by the Human Research Ethics Committee), together with a photocopy of solutions to the three problems of a class mate. The lecturer checked that no identifying names or student numbers would be visible to permit possible identification by the peer.

Importantly, half the packages contained the idealized solutions of the lecturer to each of the three problems, the other half did not. The idealized solution to Problem 8 is provided as an example in Appendix B. The Participant's Package, including Information Sheet, Consent Form and Assessor Summary Sheet, is presented as Appendix C.

Assessors had three days in which to grade the take-home hard-copy of the problems and return these with marks and annotated feedback in their packages via the school secretariat. They all agreed not to discuss the assessment, attempt to identify each other, or influence the assessment of each others' grading and, to provide as much feedback in type and form as they might like themselves as legible annotations on the hard-copy assignments. Additionally, overall or summarizing comments were invited by the lecturer on an Assessor Summary Sheet that had also been enclosed in each of the packages.

The original hardcopy solution to the three problems submitted by each student in the cohort was marked by the course tutor separately using the idealized solutions of the lecturer and the marks forwarded to the lecturer in the usual manner. A Tutor Feedback Form was used by the lecturer in this core course in which important findings raised by the tutor could be summarized and addressed in the lectures following the marking by the tutor.

The idealized solutions provided by the lecturer gave one only solution to Problems 9 and 11, but two solutions to Problem 8 (in which the Δ-point was located both graphically and analytically) (Appendix B). Importantly, these three problems cover the use of both SI and American Engineering units. They form part of a set of 14 significant tutorial problems for the one-semester level III core course in separations processing of the bachelor of chemical engineering.

A benchmarking of student grading with the tutor was not formally undertaken. This is because, this cohort had received a significant number of problems marked by the tutor together with idealized solutions in the course material and were therefore experienced with the lecturer's marking scheme. In this core course, idealized solutions were widely used by the lecturer because the greater students' experience with the lecturer's marking scheme in engineering courses the greater the "subsequent significant improvement in student performance when it comes to exams" (Brown et al., 1994). The tutor was a postgraduate chemical engineering student with a MEngSc from the school of chemical engineering who was enrolled in a PhD. He was very experienced in the course having tutored for some years for the lecturer and had an excellent rapport with the cohort.

3.4. *Student Evaluation of Learning & Teaching (SELT)*

Following peer marking, students were asked to anonymously complete a Student Experience of Learning & Teaching (SELT) survey. This was developed by the authors for this case study in collaboration with The University of Adelaide, Centre for Learning & Professional Development. The students were directed to the on-line survey instrument in *Survey Monkey®* via a link in their Participant's Package.

The survey instrument consisted of the following 10 statements and three questions:

1. All things considered, Student Peer Assessment is an effective way to learn.
2. Student Peer Assessment stimulates my interest in the course material.
3. Student Peer Assessment encourages me to better understand the course material.
4. The provision of idealized solutions is essential for successful Student Peer Assessment.
5. Student Peer Assessment stimulates discussion of key concepts out of normal contact hours.
6. My class peers mark harder than the lecturer.
7. I think Student Peer Assessment would be an effective way to learn in large classes (>50) students.
8. I would like to have Student Peer Assessment in other courses.
9. I was often forced to guess whether something was right or wrong whilst marking.
10. I was confident the marking I did was correct.
11. I received solutions from the lecturer to assist me in my Peer Assessment?
12. What are the best aspects of Student Peer Assessment?
13. Student Peer Assessment could be improved by?

Students were asked to score the extent to which they agreed or disagreed with statements 1–10 on a 7-point Likert-type scale (Likert, 1932) with 7 = strongly agree, 1 = strongly disagree, and; 4 = no opinion or neutral response. Broad agreement was defined as the percentage of responses from 5 to 7 (see for e.g. Davey, 2011). Questions 11, 12 and 13 solicited written comment(s).The timing of the research and survey coincided with weeks 11 and 12 of Semester 1, 2011.

4. Results and discussion

4.1. *Overall responses and marks awarded*

Although initial course enrolment was a cohort of a total of 71, student withdrawals (not fails) meant that a total of 64 students (21 females, 43 males) received the Participant's Package for this case study in week 11 of the 12-week semester.

Table 1 summarizes the overall raw peer assessment marks awarded to the 64 students by the student assessor and tutor. Column 1 gives the student number of each of the 64, and column 2 the student who acted as assessor. Bolding is used to identify a student who had the idealized solutions of the lecturer for their peer marking, and; *f* and *m*, respectively, indicate a female and male. For example, from Table 1, column 1, the work of student number 4 (a female) was assessed by student number 36 (a male) who did not have the idealized solutions of the lecturer. The work of student 36m was assessed (in turn) by student **4f** who had the idealized solutions.

The table usefully highlights where students did not have marks awarded to them by their assessor. For example, student **3m** (column 1) did not receive marks because his assessor 9m (column 2) did not report any. As can be seen in the table however 9m (in turn) was awarded marks by his assessor **3m**. A total of 15 students (3, 13, 15, 19, 22, 25, 29, 35, 42, 45, 51, 54, 56, 59 and 71) were not awarded marks because their assessors did not report any.

It can be seen in the table (column 2) therefore a total of 49 (=64 − 15) valid responses (18 females and 31 males) were received. This resulted in an overall response rate of 76.6% (=49/64) to the peer marking. This is actually a very high response (Nulty, 2008). No responses had to ruled invalid because, for example, marks had not been recorded, or because annotations were inappropriate or personal.

The table columns 3, 4 and 5 show, respectively, the mark awarded by the student assessor (column 2) to each of the three problems. The total mark awarded out of a possible 50 is presented in column 6. The corresponding tutor's total mark out of the possible 50 is given in column 7. It can be seen from column 7 that the tutor reported marks for all 64 students.

The granularity of marks awarded by the tutor is seen to be a 1/2 over all three problems, whereas only 12 of the 49 students (numbers 1, 4, 12, 27, 32, 34, 36, 49, 58, 60, 62, 69) were assessed with a granularity of a 1/2 in their marks by the assessors.

It can be seen from Table 1 (column 6) that the maximum mark out of the possible 50 awarded by any assessor is 49 (to students 8f, **12m**, **29f**, 63m) and the maximum awarded by the tutor (columns 7) is 50 (to **68m**, **69m**, **70f**, **71f**). The overall mean value of the marks awarded by the tutor over the 64 students was 43.8 out of a possible 50. This illustrates that the student cohort performed well against the lecturer's expectations in solving the three problems. This mean compares with 43.2 from the student assessors. However it can be seen from column 10 of the table that there were significant differences between student and tutor marks in particular cases for e.g. for student 9 m with a difference −13 (=S − T), student 17f (−9), **18m** (9), 26f (−16), **32m** (−9.5), 57m (10) and **70f** (−8). Given that the standard deviation (sdev) on both the average tutor and student assessor marks is very nearly identical at ∼5.5 (respectively, 5.7 and 5.2), there is no significant difference in marking behaviour ($p = 0.566$) (Snedecor and Cochran, 1989) overall. The minimum of 27 marks awarded to student 11 (by peer assessor 19) is however notably different from the marks awarded by the tutor of 20, and is actually the only outright fail mark awarded.

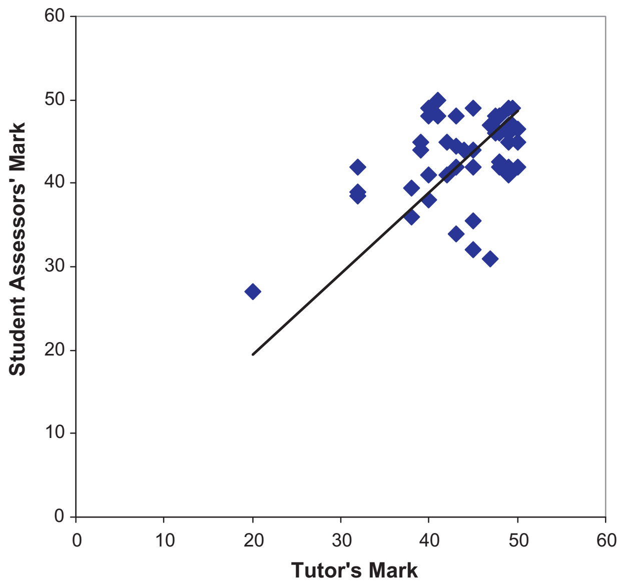


Fig. 1 – Tutor's mark versus student assessor's mark for each of 49 students.

Fig. 1 shows graphically the marking behaviour of the 49 eligible student assessors compared with that of the tutor, and serves to immediately highlight the assessment of student 11 at (20, 27). Importantly, the figure demonstrates that this data point is not an outlier because it can be seen in the figure to lie on the general line of best fit; something not obvious from the tabulated data. The conclusion is that the assessor and tutor assessments are aligned and consistent across a range of marks. This reinforces therefore that student 11 simply did not perform as well as the cohort average. The general clustering of data in the figure highlights the good agreement in marking behaviour between the student assessors and the tutor.

The corresponding value of the ratio of the mean marks of student assessor to tutor (S/T) is given in column 8 of Table 1, which for e.g. for student **4f**, assessed by student 36m, is 1.01. The table shows the values of S/T ranged from 0.66 to 1.35. This range illustrates clearly that some student assessors mark on average harder than the tutor (i.e. S/T < 1.0) and some easier than the tutor (S/T > 1.0). However, the mean assessor S/T value over the 49 students is seen from Table 1 to be 1.00 with a sdev of 0.14 i.e. the student assessors on average marked inline with the tutor on the three numerical problems but with some 14% variation in the marks of the tutor.

It is interesting to note that virtually all students used the marking technique of the lecturer and tutor; that is to initially award full marks for the problem and then show stepwise where marks are lost by progressively deducting marks and highlighting this in the annotations on the script. Also, there was no apparent anxiety expressed by any students, as may sometimes be the case (Topping, 2009).

Fig. 2 presents a plot of value of assessor S/T versus the tutor's mark and is used to investigate the spread in marking behaviour of the students in relation to the tutor, and indirectly the expectations of the lecturer. Actually shown in the figure is that 27 students were assessed harder than the tutor (S/T < 1) and 17 easier than the tutor (S/T > 1). However, it appears in the figure that approximately equal numbers of students were assessed both harder and easier than the tutor because five points lie at S/T = 1. The point (20, 1.35) is

Table 1 – Overall marks awarded to 64 students by the student assessor and tutor over three problems together with student to tutor (S/T) ratio and student/tutor difference (S–T). The use of bolding of the student number is used to identify those who had the idealized solutions of the lecturer for their peer marking; *f* and *m* indicates, respectively, a female and male.

Student number	Assessor number	Marks awarded by					S/T ratio		Difference S − T
		Assessor (S)				Tutor (T)	Assessor	Assessee	
		Problem			Total	Total			
		8 /20	9 /15	11 /15	/50	/50			
1f	60m	18	15	13.5	46.5	47.5	0.98	0.85	−1
2f	52m	20	13	13	46	49	0.94	1.13	−3
3m	9m	–	–	–	–	38	–	0.71	–
4f	36m	19.5	15	13.5	48	47.5	1.01	0.95	0.5
5m	43m	19	15	13	47	49.5	0.95	1.03	−2.5
8f	**53m**	20	15	14	49	49	1.00	1.17	0
9m	**3m**	10	11	11	32	45	0.71	–	−13
10m	27m	15	7	14	36	38	0.95	0.89	−2
11m	19m	17	10	0	27	20	1.35	–	7
12m	34m	19.5	14.5	15	49	49.5	0.99	1.20	−0.5
13m	**30m**	–	–	–	–	43	–	0.86	–
14f	**32m**	20	14	14	48	48	1.00	0.79	0
15m	**56m**	–	–	–	–	38	–	–	–
16m	61f	18	13	13	44	44	1.00	0.88	0
17f	**70f**	10	11	13	34	43	0.79	0.84	−9
18m	26f	20	15	15	50	41	1.22	0.66	9
19m	**11m**	–	–	–	–	48	–	1.35	–
20m	**68m**	14	13	15	42	43	0.98	0.90	−1
21f	**29f**	20	14	15	49	40	1.23	–	9
22m	39m	–	–	–	–	38	–	0.93	–
23m	**69m**	18	9	11	38	40	0.95	0.93	−2
24m	**49f**	20	12	14	46	48	0.96	1.04	−2
25f	45m	–	–	–	–	45	–	–	–
26f	**18m**	14	4	13	31	47	0.66	1.22	−16
27m	**10m**	17	11.5	14	42.5	48	0.89	0.95	−5.5
29f	21f	–	–	–	–	49.5	–	1.23	–
30m	13m	18	14	10	42	49	0.86	–	−7
32m	14f	10	12.5	13	35.5	45	0.79	1.00	−9.5
34m	**12m**	19.5	14.5	14	48	40	1.20	0.99	8
35m	59m	–	–	–	–	41	–	–	–
36m	**4f**	16.5	15	15	46.5	49	0.95	1.01	−2.5
37f	41m	18	15	13	46	47.5	0.97	0.84	−1.5
39m	**22m**	17	13	12	42	45	0.93	–	−3
40m	55f	18	15	15	48	48	1.00	0.98	0
41m	**37f**	16	13	12	41	49	0.84	0.97	−8
42m	63m	–	–	–	–	48	–	1.09	–
43m	**5m**	18	11	12	41	40	1.03	0.95	1
44m	**66f**	17	14	14	45	39	1.15	1.07	6
45m	**25f**	–	–	–	–	48	–	–	–
46m	**50m**	20	15	12	47	47	1.00	1.22	0
47f	62m	19	15	13	47	49	0.96	1.03	−2
48m	**65f**	20	13	12	45	49	0.92	0.98	−4
49f	24m	14	10.5	15	39.5	38	1.04	0.96	1.5
50m	46m	15	10	14	39	32	1.22	1.00	7
51m	57m	–	–	–	–	39	–	1.31	–
52m	**2f**	18	13	13	44	39	1.13	0.94	5
53m	8f	20	14	14	48	41	1.17	1.00	7
54f	58m	–	–	–	–	40	–	1.20	–
55f	**40m**	19	11	14	44	45	0.98	1.00	−1
56m	15m	–	–	–	–	38	–	–	–
57m	**51m**	18	12	12	42	32	1.31	–	10
58m	**54f**	17	12	9.5	38.5	32	1.20	–	6.5
59m	**35m**	–	–	–	–	47	–	–	–
60m	**1f**	20	10.5	11	41.5	49	0.85	0.98	−7.5
61f	**16m**	17	14	11	42	48	0.88	1.00	−6
62m	**47f**	19	11.5	14	44.5	43	1.03	0.96	1.5
63m	**42m**	20	14	15	49	45	1.09	–	4
64f	**71f**	20	13	15	48	43	1.12	–	5
65f	48m	17	14	10	41	42	0.98	0.92	−1
66f	44m	18	14	13	45	42	1.07	1.15	3

Table 1 – (Continued)

Student number	Assessor number	Marks awarded by					S/T ratio		Difference S − T
		Assessor (S)				Tutor (T)	Assessor	Assessee	
		Problem			Total	Total			
		8 /20	9 /15	11 /15	/50	/50			
68m	20m	17	13	15	45	50	0.90	0.98	−5
69m	23m	19	13	14.5	46.5	50	0.93	0.95	−3.5
70f	17f	17	11	14	42	50	0.84	0.79	−8
71f	64f	–	–	–	–	50	–	1.12	–
Average		17.6	12.7	13.0	**43.2**	**43.8**	**1.00**		**−0.73**
stdev		2.6	2.2	2.4	5.2	5.7	0.14		5.79
Max		20	15	15	50	50	1.35		10
Min		10	4	0	27	20	0.66		−16
Count		49	49	49	49	64	49		49

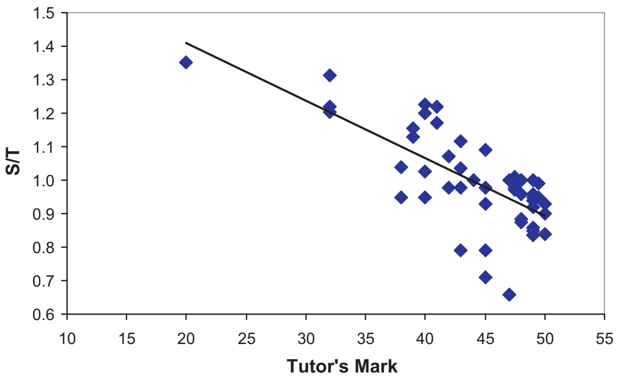


Fig. 2 – Tutor's mark versus student/tutor ratio (S/T) for each of 49 students.

for student 11 as assessed by peer 19 and shows this peer marked significantly easier than the tutor. The mark awarded by 19 can be readily obtained as 1.35 × 20 = 27. The correlation coefficient for these data of Fig. 2 is $r = 0.72$.

Fig. 3 presents a plot of the difference in marks awarded by the student assessors minus the tutor's marks i.e. (S − T) versus the tutor's mark, for each of the 49 eligible assessors. It can be seen in the figure there are 17 data with (S − T) > 0 and 27 data with (S − T) < 0 and 5 data with (S − T) = 0. The S/T ratio used in Fig. 2 however gives a more direct view of student marking behaviour in relation to the tutor. S/T is of significant value because it permits immediate recognition of any S − T relativities and aids in identifying student's marking behaviour.

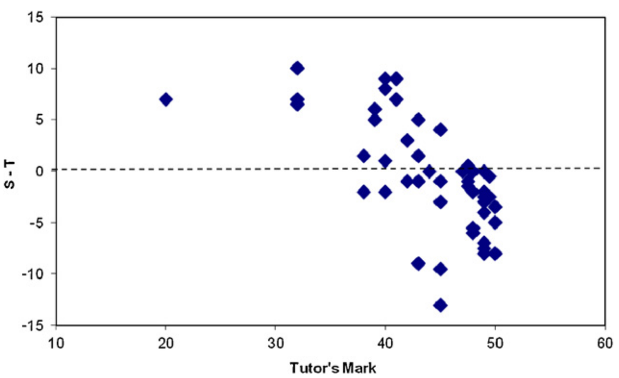


Fig. 3 – Tutor's mark versus student's minus tutor's mark (S − T) for each of 49 students.

4.2. *Gender influence*

The gender response can be determined from Table 1 as 18/21 (=86%) of eligible females and 31/43 (=72%) of eligible males actually participated fully in completing and reporting their peer marking of the three numeric problems assigned by the lecturer.

The mean mark awarded by the 18 females was 43.9 and that of the 31 males was 42.8. Both have a standard deviation of 5.2. There was no significant difference in assessors' marking behaviour with gender ($p = 0.479$) (Snedecor and Cochran, 1989).

4.3. *Idealized solutions and marks awarded*

The number of assessors with the idealized solutions that returned valid responses was 27/32 (=84%) and those without the solutions who returned valid responses was 22/32 (=69%). Therefore, proportionally more students with solutions completed the peer marking. This is not surprising as the expectation would, almost intuitively, be that the students with the idealized solutions would find the peer assessment less daunting and therefore more likely to complete it.

Table 2 summarizes and compares the marks awarded by the two groups of student assessors i.e. 27 with, and 22, without the idealized solutions for each of the three numerical problems, together with the overall means and sdev. The table highlights that overall those assessors with the idealized solutions marked marginally lower than those without with respectively means of 14.3 and 14.5. These however are not significantly different ($p = 0.77$). There is no apparent pattern across the three problems. The evidence suggests that for these problems there is actually no real difference in the two sets of data for those assessors with the idealized solutions and those without. These means compare with that of the tutor of 14.6 (=43.8/3).

To further tease out these data for the two groups of assessors, the mean overall mark for each for the three problems was plotted against the overall mean mark awarded by the tutor (Fig. 4). This figure reveals no difference in mean marking behaviour of assessors with and without the idealized solutions of the lecturer.

Table 2 – Mean mark and standard deviation (sdev) awarded by the student assessors, 27 with and 22 without, the idealized solutions over each of three problems.

Problem	Marks awarded			
	Assessor with solutions		Assessor without solutions	
	Mean	sdev	Mean	sdev
8	17.6	2.8	17.6	2.4
9	12.4	2.3	13.1	2.2
11	13.0	1.6	12.9	3.2
Overall	14.3	2.2	14.5	2.6
Count	27		22	

4.4. *Possible collusion in awarding marks*

Although students had agreed not to try to identify each other and influence the assessment tasks it appeared prudent to try to test if those students who received higher marks than the tutor from peer assessors, themselves then also marked higher than the tutor: an alternate interpretation is that those students who may have refused to mark high in exchange for high marks might be penalized with low marks for failure to collude.

To determine possible student collusion in awarding marks a plot of the marks of student assessor–assessee pairs as values of S/T were plotted e.g. from column 8 Table 1, student **4f** was assessed by student 36m with resulting assessor S/T = 1.01; in turn 36m was assessed by student **4f** with resulting assessee S/T = 0.95. From the table it is seen that there were 40 eligible students who were both acted as assessor and in turn were assessed so a resulting 20 pairs. These resulting data are presented as Fig. 5.

Collusion would be suspected if assessors who marked higher than the tutor (S/T > 1) were then also marked higher than the tutor by the assessee (S/T > 1), and; vice versa. The result would be that all the data would appear in either quadrant II or IV of Fig. 5. Inspection of this figure reveals that overall the students marked marginally harder than the tutor in that they awarded slightly less marks on average; this is indicated in the figure by the greater number of students in quadrants I and IV. There is however no systematic trend evident with an apparent uniform density of scatter around assessor–assessee values of (1, 1) i.e. the centre of the figure.

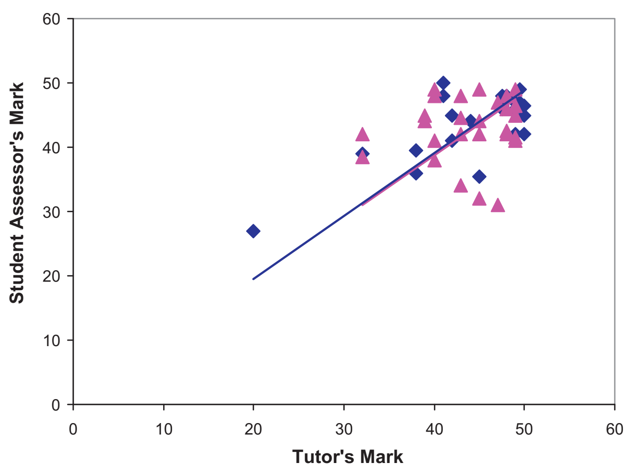


Fig. 4 – Tutor's overall mark versus student assessor's overall mark for 27 students with (▲) and 22 without (♦) the idealized solutions of the lecturer.

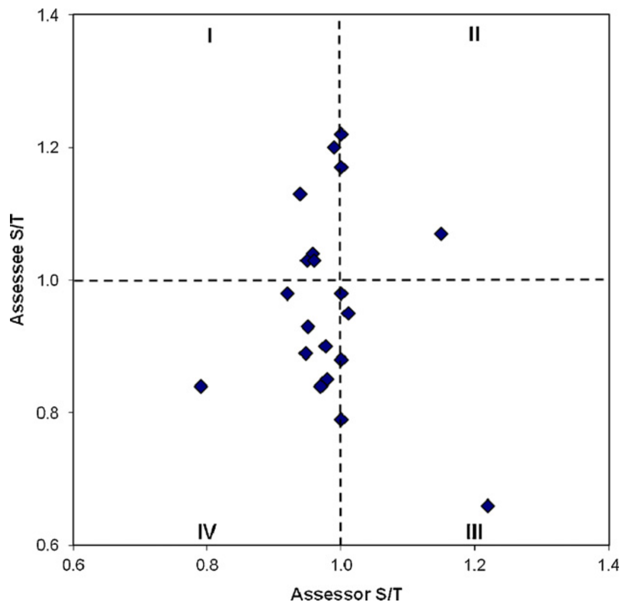


Fig. 5 – Assessor student/tutor ratio versus assessee student/tutor ratio (S/T) for each of 20 student pairs.

The evidence therefore is that there was no overall systematic, or individual, collusion between students on awarding of marks in their peer assessments. It is seen from Fig. 5 that the resulting quadrants of assessor–assessee S/T plots are actually a very convenient way of quantitatively digesting significant data (Davey, 2011).

4.5. *Annotated comments of assessors*

The annotated comments made on the hardcopy submissions by all 49 student assessors are summarized in Table 3. Column 1 is the student assessor and column 2 the student's work that was assessed. Column 1 of the table therefore aligns with column 2 of Table 1.

The overall comments written on the Assessor Summary Sheet (that was included as part of the Participant's Package) are given in column 3. Columns 4–6, respectively, present the annotations on each of the three numeric problems. Brief explanatory comments in the table are shown italicized in parentheses.

The students' overall comments on the Assessor Summary Sheet of column 3 are seen to cover a very wide range of points. These include requests for precise nomenclature and labelling (e.g. assessors **1f**, **18m**, 19m, **37f**, 48m, **54f**, 60m, **68m**); the need for clarity and quality in presentation and explanation (e.g. **4f**, 17f, 34m, 39m, 44m, **69m**); the showing of steps in working (**3m**, 14f, 17f, **22m**, 24m, **40m**, **47f**, **70f**); the need to state all

Table 3 – Summary of annotated comments provided by student assessors on the hardcopy submissions.

Student assessor	Assessed work of	Assessor annotations on			
		Assessor Summary Sheet	Specific problems		
			8	9	11
1f	60m	Legible handwriting; some errors see annotations; state clearly nomenclature	Show calculation for Δ; label flow diagram	Feed at 183.4;°F very close to sat liq at bubble pt so $q = 1$; did you count the still as a stage?	Put sign (−) on heat losses; what are your assumptions?
2f	52m	Put all notation on diagram; use a smaller scale for this graph; neat writing	Show basis for $x_S = 1 - (x_A - x_B)$; no! Partial condenser	Label carefully (*this diagram*[a])	Ideal mix = Raoult's Law
3m	9m	What exactly are the "appropriate steps" used?	Optimum S at stage 4; curve is actually "smooth"	–	–
4f	36m	Need clearer description of how graph drawn; place appropriate labelling; this does not answer the question!	Why different values here? indicate direction of feed; inconsistent labelling here	Show all information on the (flow) diagram; incorrect tie-line used	State assumed Raoult's Law
5m	43m	Clearly label (*flow*) diagram; did not actually state optimum stage; use conventions in answer; simplify (*mathematical*) expression	–	–	–
8f	**53m**	Good, easy to follow; well written	–	–	–
10m	27m	Well set out, logical and easy to follow; explains what is going on; optimum stage not actually identified Q8; incorrect derived data	Optimum stage not actually identified; hard to read	Working too compressed and hard to follow	Round-up to whole stage; diagram would help
12m	34m	Allow for reboiler as a stage; use smooth lines to draw diagram; subtract for reboiler if it is an equilibrium stage; use linear interpolation; good to see assumptions stated!	Use a bigger graph, will look neater (*for reader*)	Don't add for PR (*partial reboiler*)	If using (*software*) package be sure to check all data (*inputs*); give whole numbers for stages; be careful to answer what you are (*actually*) asked; why are you adding (*stages*) here?
13m	**30m**	Equilibrium stages should be in whole numbers; good explanation; title (name) your graph	–	–	–
14f	**32m**	Need to show all working; diagram not big enough; overall good	Not a total condenser; minimum stages!; you actually found 8 stages!	Total, not partial	You found 8 equilibrium stages!
16m	61f	Only error in $\Delta_n V_1$; theory correct; graph inaccurate; led to inaccuracies in results; must (*first*) derive equation for condenser duty; graphs good quality and easy to read	–	–	–
17f	**70f**	Need better explanation for what you did, working however correct; great correct balance	Explain how points L_n, V_1, Δ_n are located	Need to (*continue*) to step off all way to B_1	–

18m	26f	Mostly good, one mistake in principle (read wrong graph); need to define terms better; Did you read carefully the question?; very good	Explain a bit more what you are doing here	“Carefully” label this diagram; answer (*directly*) the question!	State assumption; try to be a bit more accurate (*on the graph*)
19m	**11m**	Unclear (what) steps used to obtain answers; V_1 cannot be located before Lever Rule used; No labels!; write legibly!	The ethanol for this problem is stated as 35% not 365!	–	–
20m	**68m**	Overall quite good; good understanding of problem (*shown*); easy to follow; must include all units!	Good diagram; need to be a bit neater	Label extract/raffinate; elaborate on whether to round up or down	Kudos for the extra effort put into this answer! good precise explanation
22m	39m	Plot graph carefully and label it; show all calculations; be specific (*when answering*)	Plus partial reboiler!	–	–
23m	**69m**	Well answered; bit messy and hard to read here; could include more working; use larger graph to aid reader	Convention is dotted lines for stages	Provide (*details of*) mass balance	–
24m	**49f**	Lack of working (*shown*); untidy in parts; McCabe Thiele might not be best; lack of working shown; method ok but values low	Not consistent!!; expand graph for better resolution	No working shown	Differs from my value probably due to gradient method
26f	**18m**	Explanation for graph was very detailed and thorough (better than me); graph for this question too small; student gave more than was asked; explanation given was very helpful. I didn’t do this problem and this helped me understand what was happening.	–	–	–
27m	**10m**	Missing data on equilibrium table; “horrible” resolution on graph; accuracy?; this was done in a slip-shod fashion; very neat work (for this problem); some effort obvious; handwriting neat, inclusion of all steps (*to problem solving*) is good	“*D*” or “*L*”?; show calculations for x_S and y_S; use higher resolution to increase accuracy	10 actual plus reboiler!	Inaccuracy; state assumption that reboiler = 100% efficiency
29f	21f	Methodology clearly outlined; well rounded solution; clearly well done	–	Optimum feed plate = 5th ideal stage = 7th actual stage	–
32m	14f	Just need to be really careful when grading; no major errors anywhere	Rounding off here	Good observation	–
34m	**12m**	More needed to explain why V_1 lies on line connecting L_0 and V_0; method well-explained; neat answers and graph; process well-explained; all steps clearly explained	Explain why V_1 located on this line!	Too many significant figures!	Equate to Dalton’s (*law*)
36m	**4f**	Label headings on graphs; concise and clear!; correct derivation; rounding errors for plates	Label?	–	–

Table 3 – (*Continued*)

Student assessor	Assessed work of	Assessor annotations on			
		Assessor Summary Sheet	Specific problems		
			8	9	11
37f	41m	Overall good, however seems to be confused bet(*ween*) mixed and total condenser; clear explanation; should check stepping off stages; diagram should be (*better*) labelled and use separate page for graph	Why?; total since $L_0 = D$; tie line	Label diagram fully; optimum feed plate = 5th ideal stage = 7th actual stage	Label this
39m	**22m**	Neat concise answer; would like more explanation of steps taken to final answer; show all steps; good!	How was this found?	Can you use a mass balance here?	"Smoothly"
40m	55f	Theory was right, needed to show how you calculated your aniline wt%; there was an error in the graph which threw your numbers out for the rest of the question; inaccuracies in graph lead to incorrect answers	–	–	–
41m	**37f**	Very well set out; graph was not labelled; done well; error in rounding	No labels	–	Rounding error; part f missing
42m	63m	(*Student*) did a great job in answering this question; steps taken are written clearly; calculation method ok but slight error in answers	–	–	Well answered
43m	**5m**	Very well set out, every step well explained; good graph; difficult to see points and tie lines on graph; rounding error	Should state definitions e.g. a = methylcylohexane, etc.	–	Show partial and total; did you use simultaneous eqns or (*software*) Solver?; different from what your chart says
44m	**66f**	Logical, intentions stated and worked efficiently; please explain where you got "13 units" draw connecting lines; fantastic Q11!	–	–	–
46m	**50m**	Very good, graph a little hard to read, seems correct; high quality; part e Q11?	–	–	–
47f	62m	Don't forget line above i.e. $V_1 L_0$; units?; add some description of what you are doing; show conversions from mass fractions; try to write more neatly	–	Show how you got them (F and B); something missing?; how did you convert?	Bit messy
48m	**65f**	No professional(ly) labelled diagram	Where is Fig. 2?	–	Label this diagram professionally; show the relevant equation

49f	24m	Neatly set out; shows logical progression; easy to read graph; good list of assumptions; method is correct but answer actually wrong	–	Flow rate too big!	–
50m	46m	Equilibrium diagram drawn incorrectly L_0, D not shown; answer poorly presented Q8	Confused aniline with n-heptane	Diagram incorrect	Well done
51m	57m	–	Plot points on the graph; bigger graph needed	–	–
52m	**2f**	–	Presented in a clear way; good explanation	–	Student has not fully addressed question
53m	8f	–	Well presented, clear logic	Graphical error, but overall good	Have clearer assumptions
54f	58m	Label all curves on graph; include all block diagrams and mass and energy balances; take care in reading off the graph (*stepping off*); define all nomenclature	$\Delta_n = L_0 - V_1$ all co-linear	Include $x = y$ line on diagram and label raffinate and extract curves	Define A, B??
60m	**1f**	Make sure to label curves i.e. raffinate and extract	Label curves	–	Might have been easier to read if graphs for part c and d were on separate axes
61f	**16m**	Well written and working shown step by step	–	–	–
62m	**47f**	State assumptions	How did you get 8?		
65f	48m	–	–	–	–
66f	44m	Should answer all (*parts of*) questions	Process right but accuracy bad	–	–
68m	20m	Graphs should be clearly drawn and should have titles with units; try to select total or partial condenser; need better understanding about notations	No liquid (not vapour); feed stage is where tie line crosses the feed line; difficult to see how many tie lines	Some values (x) are not correct	Neatly done
69m	23m	How you found Δ is not introduced	I suggest you state how you found Δ_m; partial condenser	There is a little misunderstanding of Lever Arm Rule	Should show your own equilibrium diagram; use integer
70f	17f	Show more calculation steps	How many optimum feed stages?	–	–
71f	64f	–	It would be better to record all the data with same accuracy	Try to explain $x_F = 0.35x$ (*ethanol*) at 183.4 °F	–

[a] Authors explanatory comments throughout are shown italicized in parentheses.

working assumptions (**22m**, 24m, 62m, **69m**); rounding and other errors (**16m**, 27m, 36m, **40m**, 41m, 43m, **54f**); use of conventions (in the discipline) (**5m**); the need to answer all (parts) of questions (46m, **66f**), and; requests for general neatness (19m, 23m, 24m, **47f**, **50m**).

Significant positive assessor comments appear regarding (legible and neat) handwriting and general neatness (e.g. assessors **1f**, 8f, **16m**, 39m, 43m, 61f); precision in nomenclature and labelling (36m); logical approaches to problem solving and setting out of the solution (**10m**, 20m, 23m, **29f**, 34m, 39m, 41m, 44m, **49f**); clear statement of working assumptions (**12m**), and; the demonstration of understanding of the course material (**18m**, 20m). Indeed assessor 26f states that her assessment task directly "... helped me understand what was happening..." and **42m** that "(student) did a great job in answering this question; steps taken are written clearly". Student assessors seemed to appreciate any obvious effort made by the student (20m (column 6), 27m, **49f**).

From the annotations overall on specific problems (columns 4, 5 and 6 of Table 3) it can be seen that on a technical level students were quick to point out errors in understanding of partial and total re-boilers (a reoccurring element in threshold concepts in this core course, Davey, in review); the need to state assumptions regarding ideal mixtures, and; whether commercial software was used in the solutions (**12m**, 43m).

It is significant that there are no examples of using the peer assessment opportunity to make criticisms of a particular student and work assessed. The experimental design meant that it was not readily possible to identify whose work they were marking in any event, so that comments could therefore not be targeted.

The comments from the student assessors are consistent with the tutor's general comments, but are more detailed. This is expected as students had only the work of one other to assess, whereas the tutor had many more. The comments are of a good standard and the style used is similar to that students will have experienced themselves in their studies at earlier levels in the degree program. Similar student comments, although more limited, were reported by Davey (2011).

It is clear from the overall data of Table 3 that students all had engaged positively in the peer assessment task in attempts to give feedback that they themselves might appreciate; they clearly understood that feedback comments are valued in learning the course material.

4.6. *Student Experience of Learning & Teaching (SELT)*

A comparative summary of the SELT survey findings, statements 1–10, is presented as Table 4 (statement 11 of the survey being whether the student assessor did or did not have the idealized solutions of the lecturer). The data are presented as the mean Likert score and sdev, together with % broad agreement and actual number of respondent student assessors, with and without the idealized solutions.

As is seen from the table there were 23 responses from the 27 student assessors with, and 21 responses from the 22 students without, the idealized solutions of the lecturer. The response rate, respectively, therefore was 85% from students with the idealized solutions (23/27) and 95% from students without the idealized solutions (21/22). Both these response rates are considered high (Nulty, 2008).

Column 10 of the table presents the difference in % broad agreement (as the value of assessors with *minus* value of assessors without, idealized solutions of the lecturer). It can be seen from column 10 of this comparative table that there was most agreement between the two groups with survey statements 6 and 5 (with respectively, differences of −3 and 5) i.e. student assessors both with and without the idealized solutions agreed that in peer assessment their class peers did not mark harder than the tutor (respectively, 30 (21/23) and 33 (18/21) % broad agreement), and; that the peer exercise did stimulate discussion of key concepts out of normal contact hours (respectively, 91 (21/23) and 86 (18/21) % broad agreement). The low values of agreement to statement 6 from both assessor groups (respectively, 30 and 33%) are interpreted as most students (>67%) in this cohort having confidence in the marks awarded to them in the Peer Assessment.

Perhaps it is not surprising that there is the least agreement between the two groups on statement 9 (difference = −38). In fact, as evidenced in column 11 by the value $p = 0.0016$ (Snedecor and Cochran, 1989), this is actually one of only two statically significant differences in the raw Likert responses from the two groups (the other being for statement 4 with $p = 0.0022$). With a 95% broad agreement (20/21) to statement 9, it is apparent that those assessors without the idealized solutions felt they were potentially disadvantaged whilst marking in being forced to guess whether something was right or wrong. This finding might actually have been expected; as too, was that those without the idealized solutions were consequently less confident in what they marked was correct (survey statement 10 with difference = 21).

The results to survey statement 7 might be expected to follow therefore in that less than half the assessors (10/21) without the idealized solutions felt confident that peer assessment would be an effective way to learn in large (>50) classes (48% broad agreement); whereas, those with the idealized solutions felt more positive with 19/23 respondents (83% broad agreement) stating peer assessment would be would be an effective way to learn in large (>50) classes.

Although 90% of the assessors without the idealized solutions stated they felt them essential for successful peer assessment (statement 4) the actual marks awarded and marginality are very nearly identical between the two groups (Table 2). If the marks of the tutor can be used a reliable guide, then overall, the student assessors without the idealized solutions therefore actually performed better than they appear to have thought.The responses to all 10 survey statements can be conveniently summarized graphically and are presented as Fig. 6. It is immediately apparent from this summary that students as assessors, respectively statements 1–5, overwhelmingly agreed that peer assessment is an effective way to learn; stimulated interest in the course material; encouraged better understanding; was enhanced with provision of the idealized solutions, and; that discussion outside of normal hours was stimulated. It is important to again caution however that the only statistically significant differences in Likert scores for this comparative plot can be seen from Table 4 to be those for statements 4 ($p = 0.0217$) and 9 ($p = 0.0016$), although statements 7 and 8 are nearly statistically significantly different since p values are nearly 0.05.

The written comments of the student assessors to Q12 and Q13 of the SELT are presented in Table 5. It is immediately interesting to note the actual number of comments. From the 23 assessors with the idealized solutions there were 13 responses to Q12 and six to Q13, whereas from the 21 assessors without the idealized solutions there were, respectively,

Table 4 – Likert score SELT summary for Statements 1 to 10 on Peer Assessment on 23 responses from 27 student participants with, and 21 responses from 22 without, the idealized solutions of the lecturer. (Likert 7 = strongly agree, 1 = strongly disagree, and; 4 = no opinion or neutral response.)

SELT statement	Student assessor								Difference	p
	With idealized solutions				Without idealized solutions					
	Mean	sdev	% broad agreement	Responses /23	Mean	sdev	% broad agreement	Responses /21	% broad agreement	
1	5.3	1.3	83	19	5.3	1.1	76	16	7	1
2	5.0	1.2	78	18	4.9	1.3	67	14	11	0.7920
3	5.3	1.2	87	20	5.3	1.5	76	16	11	1
4	5.1	1.5	74	17	6.0	0.9	90	19	−16	0.0217
5	5.4	1.2	91	21	5.2	1.0	86	18	5	0.5535
6	4.3	1.1	30	7	4.5	1.4	33	7	−3	0.5994
7	5.1	1.2	83	19	4.3	1.8	48	10	35	0.0876
8	5.0	1.6	65	15	4.2	1.5	48	10	17	0.0953
9	4.6	1.7	57	13	6.0	0.9	95	20	−38	0.0016
10	5.1	1.3	78	18	4.4	1.6	57	12	21	0.1174

1. All things considered, Student Peer Assessment is an effective way to learn.
2. Student Peer Assessment stimulates my interest in the course material.
3. Student Peer Assessment encourages me to better understand the course material.
4. The provision of idealized solutions is essential for successful Student Peer Assessment.
5. Student Peer Assessment stimulates discussion of key concepts out of normal contact hours.
6. My class peers mark harder than the lecturer.
7. I think Student Peer Assessment would be an effective way to learn in large classes (>50) students.
8. I would like to have Student Peer Assessment in other courses.
9. I was often forced to guess whether something was right or wrong whilst marking.
10. I was confident the marking I did was correct.

15 and 10. This means that, overall more than a half of all students made written comments, a high number (Nulty, 2008).

For those students with the idealized solutions it is clear from the comments to Q12 (What are the best aspects of Student Peer Assessment?) that it was widely agreed that as assessors they learned at the same time whilst marking the work of another; (11 of the 13 comments explicitly state this). Only one comment refers explicitly to having the idealized solutions of the lecturer as an advantage in their learning the course material. The theme in the 11 comments to the SELT is that the peer task helped individual learning through seeing the work and methods of another student. For those assessors

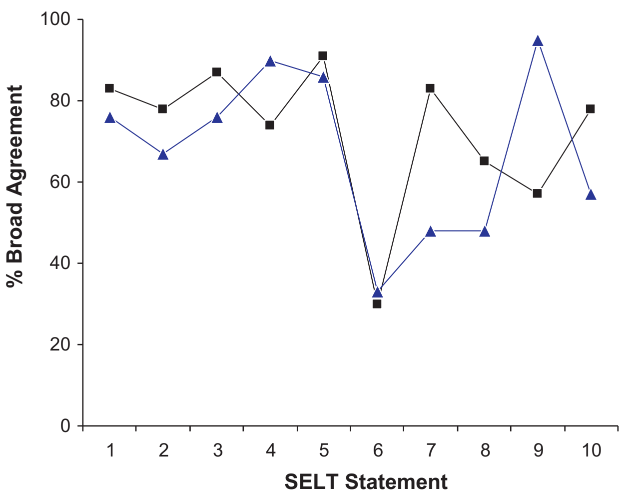


Fig. 6 – Comparative plot of broad agreement on 23 responses from 27 student participants with (■), and 21 responses from 22 without (▲), the idealized solutions of the lecturer to SELT Survey statements 1 to 10 on Peer Assessment.

without the idealized solutions 14 of the 15 comments to Q12 in column 3 of Table 5 also state explicitly that their learning was enhanced in the peer grading of another's work.

It is clear overall from the comments in Table 5 that students benefited by gaining a deeper understanding that there was more than one way of solving a problem. This is actually the level in the degree program that students do begin to understand this. Importantly, by way of example, the lecturer provided two solutions to Problem 8 (see Appendix B). This same overall finding was reported by Davey (2011).

For those students with the idealized solutions it is clear from the six comments to Q13 (Student Peer Assessment could be improved by?) that there is no general theme. A major concern was the timing of the SELT (too near exam preparation time). An interesting suggestion is that the assessors be given only a solution to a half the problems so as to experience the "best of both worlds" i.e. be able to grade both with and without idealized solutions in their peer assessment task. More tellingly however is the one comment suggesting improved ("detailed") guidelines on the assessment marking. This comment does not however resonate with the majority view.

From those assessors without the idealized solutions, the 10 suggestions to improve Student Peer Assessment cover a wider range of issues than those assessors with the idealized solutions, namely; provision of the solutions of the lecturer (1 comment), more detailed marking scheme (2) and timing too near exams (1). The one comment suggesting more time (than the three days allowed in this study) was needed to complete this peer assessment task possibly reflects the fact that this assessor consulted widely the course lecture notes as an aid to grading. One comment illustrates that at least one assessor without the idealized solutions was not sure whether the peer assessment was "liked" or not; an issue reflected in a comment to Q12 of the SELT for this group.

Clearly, however, the SELT results of Table 5 demonstrate that the peer assessment task was overwhelming viewed as a

Table 5 – Student Experience of Learning & Teaching (SELT) survey summary for Questions 12 and 13 on Peer Assessment with, and without, the idealized solutions of the lecturer.

SELT question	Student assessor	
	With idealized solutions	Without idealized solutions
12	Sometimes it's hard to follow a fellow student's ideas, but the given solution was a great help to us	A guide to solve examination questions
	Learn different ways by looking at other student's method	Reading other people's work, and seeing what they did right or wrong
	Helps to see other ways of doing questions than what I did myself	It encouraged me to consider whether I was right or wrong, and thinking about the important concept
	Peer assessment helps your understanding of concepts, as well as understanding of how others answers differ from your own	Often alternate solutions can be seen, but in this case as most of the tutorial work was collaborative, most alternate methods had been seen/used
	Allows the opportunity to see how other students completed their assignments	Get to evaluate different methodologies by other students and how they approach questions that you have also attempted
	You see how others approached the question and learn what is a better approach to your own, in certain cases	The marking of someone else's tute stimulated me to learn more about questions I didn't do in my group
	I learnt how best to present an answer so the marker can follow with ease. The things which help make a good answer are: statements as to what is being found, clear definitions of terms, clear steps for derivations, displaying understanding of the question through written comments	Opportunity to view alternate methods to solving problems, other than my own. Sometimes these methods are less rigorous, and therefore are useful
	To analyse where the marks should be allocated and understanding your course mate thinks when solving the problems. You can know what aspects of the course that must be mastered from another student's point of view	Seeing how another person completed the problem. They completed the whole derivation of question 11 whereas we could not find that solution
	Can learn at the same time while marking	We get to see how others solve a problem, and learn from their mistakes
	Got to see how other groups solved the problems and was able to compare with how I did	There is not a whole lot that I liked about this task
		It gets you thinking about the marking scheme and also will help you remember methods easier
		Another way in which we can better learn/understand the course material
	1. It reveals the many different and creative ways to solve the same problem. 2. You learn very quickly from others mistakes. 3. It encourages reviewing the fine detail of the course in order to mark the problems	Stimulates thinking about the assessor's own approach to the question and how they varied
	A good chance to learn other methods of solving a given problem	Learning from others mistakes/methods
		It encouraged the student to look for the details of other students work
13	I couldn't find anything wrong with the assignment I was marking, so there was nothing to comment on, besides ticking things	Showing an example to solve one question and follow the similar kind of question for practice
	Having the assessment earlier in the term so we aren't so busy finishing classes and studying for exams	Should give us the solutions and do this (*peer*) assessment during the semester not in the end of the course
	Tutorials marked multiple times in order to remove inconsistencies	(*More detailed*) marking scheme
	Maybe give each student half the solutions (for example, if there were two problems, give the solutions to one problem). This way the student gets the "best of both worlds"	Undecided whether I like it or not
	More detailed guidelines on how to mark the paper e.g. what range of answers are accepted etc.	Provision of a marking scheme, so that peers do not mark too strictly and if final numerical answer is wrong, students know how to give marks based on method followed
	Not providing idealized solutions to the problem. This encourages assessment of the solutions and any mistakes made	Would have liked the solutions, had to go on the work which I did, which am unsure if it was correct
		More (*time*), as we need to refer back to the theory
		At this time of year when assignments are in their greatest numbers, I think it would be best if a peer assessment was conducted earlier in the semester or maybe even not at all
		Being given more time to complete, was busy on the weekend so didn't give it the time I thought it deserved
		The lecturer's solutions probably need to be provided if peer assessment is used for actual marking. If it is only used as a learning tool I think it would actually be more effective without the lecturer's solutions

12. What are the best aspects of Student Peer Assessment?
13. Student Peer Assessment could be improved by?

positive learning experience by this cohort. It is concluded that the student assessors were deeply engaged (Ballantyne et al., 2002) in their learning through this peer assessment study.

To summarize, analyses of independently administered SELT survey results indicate overall that more than 3/4 of all assessors, both with and without the idealized solutions, agreed that all things considered, that Student Peer Assessment is an effective way to learn (Table 4), and; it encouraged better understanding of the course material (Table 5). It is noteworthy from Table 4 that for both these statements $p = 1$, indicating there was no significant difference whatever in the Likert scores from the two groups. However differences in the two groups did emerge in response to the two related issues of provision of idealized solutions ($p = 0.0217$) and the need to guess whether in their marking something was actually right or wrong ($p = 0.0016$). A consequence is that the students without the idealized solutions were less likely to want to have Student Peer Assessment in their other courses ($p = 0.0953$).

5. Conclusions

There is no statistical difference ($p > 0.05$) in the mean marks awarded by the two groups, those with and without, the idealized solutions of the lecturer, to three significant numeric tutorial problems in a core chemical engineering separations course. The mean mark for the two groups were, respectively, 14.3 (sdev 2.2) and 14.5 (sdev 2.6). Despite this excellent agreement in mean marking there were notable differences between student assessors and tutor marks in particular cases however.

Proportionally more students with solutions completed the peer marking (84%) than those without (69%). This is interpreted as those students with the solutions found the peer assessment task less daunting to complete than those students without the solutions.

The granularity in marking for both groups was a 1/2. The marking technique used by assessors in both groups reflected that “learned” from the lecturer and tutor. This was to initially award full marks for the problem and then show in steps where marks were lost by deductions and highlighted on the script. There is no evidence of either systematic or individual student collusion affecting marking behaviour.

More than 3/4 of all assessors, both with and without the idealized solutions, agreed that, all things considered, Student Peer Assessment is an effective way to learn, and that peer assessment encouraged better understanding of the course material. There was no significant difference ($p > 0.05$) in Likert scores from the two groups.

However differences between the two groups were found in response to two related issues, the provision of idealized solutions ($p = 0.0217$) and the need to guess whether in their marking something was actually right or wrong ($p = 0.0016$). A consequence is that the students without the idealized solutions were marginally less likely to want to have peer assessments in their other courses ($p = 0.0953$).

Providing idealized solutions has been indicated as a key factor in this peer assessment study. Other factors that may be of importance are providing sufficient time to complete the task, and making the task a compulsory part of the coursework. It is worth noting that in this study, students were not making a final judgement on another’s work. This was done by a tutor. Had students been the arbiters in a summative assessment, the level of cooperation and learning gained may have been offset by the anxiety of knowing that one student’s fate depended on another. For formative peer assessment however it is likely that student engagement and attitudes will match closely findings reported here.

Acknowledgement

The authors wish to gratefully acknowledge the student participants in this research.

Appendix A. The Numeric Problems

8. Methylcyclohexane is being extracted from n-heptane using aniline as the solvent in a counter-current operation with extract reflux. Use the operating conditions and the equilibrium data listed below to calculate the number of equilibrium stages required and the optimum feed stage. [20 Marks]

Data

Feed rate: $100\,kg\,h^{-1}$

Internal reflux ratio: 0.115

Stream composition:

Stream	Methylcyclohexane (wt%)	n-Heptane (wt%)	Aniline (wt%)
Feed	45	55	–
Solvent	–	2	98
Recovered solvent	–	0.3	99.7
Raffinate product	20	?	?
Extract product	85	10	5

Equilibrium data for methylcyclohexane, n-heptane and aniline:

Hydrocarbon phase (wt%)		Aniline-rich phase (wt%)	
Methylcyclohexane	n-Heptane	Methylcyclohexane	n-Heptane
0.0	92.6	0.0	6.2
9.2	83.1	0.8	6.0
18.6	73.4	2.7	5.3
22.0	69.8	3.0	5.1
33.8	57.6	4.6	4.5
40.9	50.4	6.0	4.0
46.0	45.0	7.4	3.6
59.0	30.7	9.2	2.8
67.2	22.8	11.3	2.1
71.6	18.2	12.7	1.6
73.6	16.0	13.1	1.4
83.3	5.4	15.6	0.6
88.1	0.0	16.9	0.0

9. A fractionating column is operating at 1 atmosphere pressure to produce a reflux and distillate product containing 90 wt% ethanol and the balance water, and a bottoms product containing 1.0 wt% ethanol. The feed contains 35 wt% ethanol and is introduced at 183.4 °F at a rate of 1000 lb/h. Reflux is returned to the top plate of the column at a rate of 1170 lb/h. [15 Marks]

(a) How many actual plates (in addition to the still) are required with an overall plate efficiency of 70 per cent? Assume the still equivalent to one ideal plate. [8 Marks]
(b) What are the rates of heat transfer in the still and in the condenser? [4 Marks]
(c) At what rate does vapour leave the still, and what is its composition? [2 Marks]
(d) To the downspout of which actual plate should the feed be introduced? [1 Mark]

Assume equal plate efficiencies in the stripping and rectifying sections.

11. A mixture containing 30 mol% benzene and 70 mol% toluene is to be fractionated at 1 atm in a distillation column which has a total condenser and, a still from which the bottoms are withdrawn. The distillate is to contain 90 mol% benzene and the bottoms 4 mol% benzene. The feed is at its dew point. [15 Marks]

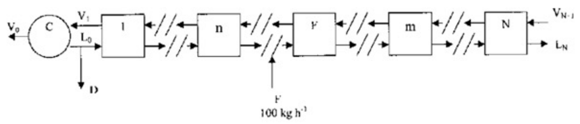
(a) What is the minimum reflux ratio? [2 Marks]
(b) What is the minimum number of equilibrium stages in the column required (at total reflux)? [3 Marks]
(c) How many equilibrium stages are required at a reflux ratio of 8.0? [3 Marks]
(d) How many equilibrium stages would be required at a reflux ratio of 8.0 if the feed were a liquid at its bubble-point? [3 Marks]
(e) How many actual stages are required for an overall column efficiency of 60%? (Part (c) conditions) [1 Mark]
(f) Derive an expression for the condenser duty. [3 Marks]

Vapour pressure–temperature data:

T (°C)	Vapour pressure (mm Hg)	
	Benzene	Toluene
80.1	760	–
85	877	345
90	1016	405
95	1168	475
100	1344	557
105	1532	645
110	1748	743
110.6	1800	760

Appendix B. The Lecturer's Idealized Solutions to Numeric Problem 8

Q. 8



Let
A: methyl-cyclohexane (solute)
B: n-heptane (diluent)
S: aniline (solvent)

$F = 100$ kg h^{-1} $\frac{L_0}{V_1} = 0.115$ (internal reflux ratio)

Calculate (*see* table below) and plot equilibrium data – *see* Fig. 1 Q. 8:

hydrocarbon phase (wt%)			aniline-rich phase (wt%)		
Meth'hexane x_A	n-heptane x_B	aniline $x_S = 1 - (x_A + x_B)$	Meth'hexane y_A	n-heptane y_B	aniline $y_S = 1 - (y_A + y_B)$
0.0	92.6	7.4	0.0	6.2	93.8
9.2	83.1	7.7	0.8	6.0	93.2
18.6	73.4	8.0	2.7	5.3	92.0
22.0	69.8	8.2	3.0	5.1	91.9
33.8	57.6	8.6	4.6	4.5	90.9
40.9	50.4	8.7	6.0	4.0	90.0
46.0	45.0	9.0	7.4	3.6	89.0
59.0	30.7	10.3	9.2	2.8	88.0
67.2	22.8	10.0	11.3	2.1	86.6
71.6	18.2	10.2	12.7	1.6	85.7
73.6	16.0	10.4	13.1	1.4	85.5
83.3	5.4	11.3	15.6	0.6	83.8
88.1	0.0	11.9	16.9	0.0	83.1

Summary of stream composition:

Stream	Mass fraction A	Mass fraction B	Mass fraction S
F	0.45	0.55	0.00
V_{N-1}	0.00	0.02	0.98
V_0	0.000	0.003	0.997
L_N	0.20	(?) 0.72 **	(?) 0.08 *
D, L_0	0.85	0.10	0.05

** By difference i.e. $1 = x_A + x_B + x_S$
* From equilibrium raffinate curve, since L_N leaves an equilibrium stage

Locate and plot points corresponding to streams: D (L_0), F, V_0, V_{N+1}, L_N
L_N lies on the equilibrium raffinate curve
Points V_0, V_1, D and L_0 are co-linear
∴ line $\overline{DV_0}$ intersects the equilibrium extract curve at V_1
– (V_1 leaves an equilibrium stage)

From Fig. 1 Q. 8 composition of V_1:
$y_{A1} = 0.125$ $y_{S1} = 0.86$ $y_{B1} = 0.015$ (i.e. 1-(0.125 + 0.86))

Location of Δ point needed for stage calculations:
For LHS of feed (stage n)

$$\Delta = \Delta_n = L_n - V_{n+1} = L_0 - V_1 \quad (1)$$

Δ, L_0 and V_1 are co-linear
position of Δ can be found **graphically**:
Internal reflux ratio: $\frac{L_0}{V_1} = 0.115 = r$
Based on Eqn (1) lever rule gives:
$\frac{L_0}{V_1} = \frac{\overline{\Delta V_1}}{\overline{\Delta L_0}} = r = 0.115$

Alternatively:
$\frac{L_0}{V_1} = \frac{\overline{\Delta V_1}}{\overline{\Delta L_0}} = 0.115$
$\overline{V_1 L_0} = 158 \text{ mm} = \overline{\Delta L_0} - \overline{\Delta V_1} = \overline{\Delta L_0} - 0.115 x \overline{\Delta L_0}$
$0.885 x \overline{\Delta L_0} = 158$ mm
→ $\overline{\Delta L_0} = 178.5$ mm

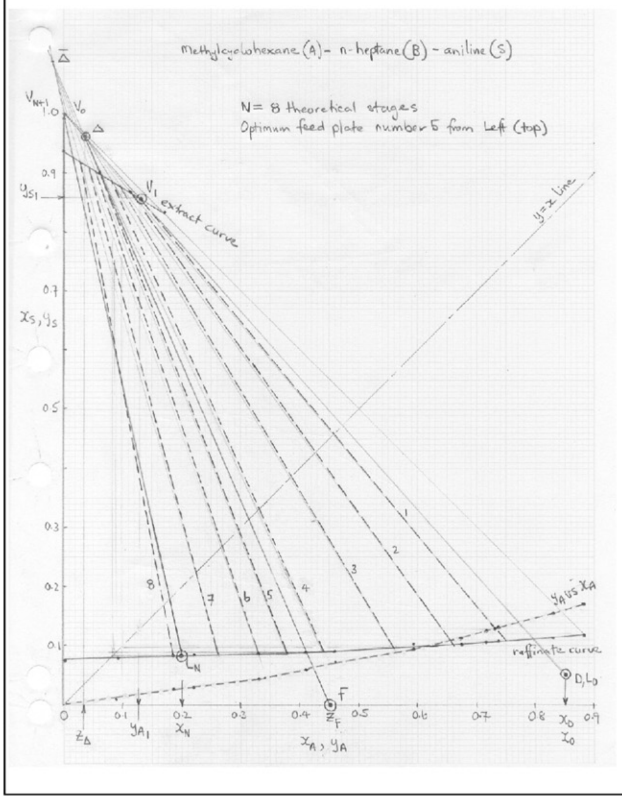
Δ may lie between points V_0 and V_1 case (a)
or may lie between points V_1 and L_0 case (b)

(a) is the case – this is shown as follows:
if (a) $\overline{\Delta L_0} = \overline{\Delta V_1} + \overline{V_1 L_0}$
∴ $\frac{\overline{\Delta V_1}}{\overline{V_1 L_0}} = \frac{r}{1-r} = 0.130$ => point Δ located
i.e. since $\overline{V_1 L_0} = 216.5$ mm ∴ $\overline{\Delta V_1} = 216.5 \times 0.13 = 28.2$ mm

Location of $\overline{\Delta}$:
For RHS of feed (stage m)
$\overline{\Delta}$ is found at the intersection of line $L_N V_{N-1}$ and FΔ

Can now step off equilibrium stages using Δ and $\overline{\Delta}$ Fig. 1 Q. 8. From construction:

- $N \approx 8$
- Stage five (5) from LHS (top) is the optimum feed stage



Q. 8 – **POSTSCRIPT**

Position of Δ can be found **analytically** also i.e:
Using definition of Δ and balance around refluxes:

$$\Delta = L_0 - V_1 = -(V_0 + D) \quad (2)$$

$$\Delta = r V_1 - V_1 = (r-1) V_1 \quad (3)$$

A balance (net flow):

$$\Delta z_\Delta = -(V_0 y_0 + D x_0)$$

$$= -(V_0 (0) + D x_D) = -D x_D$$

$$\therefore z_\Delta = \frac{-D x_D}{\Delta} = \frac{-D x_D}{(r-1) V_1} = \frac{x_D}{(1-r)} \frac{D}{V_1} \quad (4)$$

Balance around refluxer:

$$V_1 = V_0 + D + L_0$$

$$\therefore (D + L_0) = V_1 - V_0 \quad (5)$$

A:

$$V_1 y_1 = 0 + (D + L_0) x_D = (V_1 - V_0) x_D \quad (6)$$

$$(6) \Rightarrow V_1 = \frac{x_D}{x_D - y_1} V_0 \quad \text{or} \quad \frac{V_0}{V_1} = [1 - \frac{y_1}{x_D}] \quad (7)$$

$$(2) \Rightarrow D = V_1 - V_0 - L_0$$

$$\therefore \frac{D}{V_1} = [1 - \frac{V_0}{V_1} - \frac{L_0}{V_1}] = [1 - \frac{x_D - y_1}{x_D} - r] = [\frac{y_1}{x_D} - r] \quad (8)$$

Substitute Eqn (8) into Eqn (4):

$$z_\Delta = [\frac{x_D}{1-r}](\frac{y_1}{x_D} - r) = \frac{0.85}{(1-0.115)}(\frac{0.125}{0.85} - 0.115) = 0.0308 \approx 0.03$$

This implies point Δ is between V_0 and V_1 as $y_0 < z_\Delta < y_1$.
Knowing z_Δ, point Δ can be readily located. Checking:

$$\frac{\overline{\Delta V_1}}{\overline{\Delta L_0}} = \frac{28.5 \text{mm}}{245 \text{mm} V_1} = 0.116 \approx \frac{L_0}{V_1} = r = 0.115 \ \surd$$

Appendix C. Participant's Package including Information Sheet, Consent Form and Assessor Summary Sheet

THE UNIVERSITY OF ADELAIDE AUSTRALIA

THE UNIVERSITY OF ADELAIDE
HUMAN RESEARCH ETHICS COMMITTEE

INFORMATION SHEET

Document for people who are participants in a research project

Research Study Entitled:
Student peer assessment: A research study in a level III core course of the bachelor chemical engineering degree program

Purpose:
- The purpose is to establish whether active peer assessment is a valid and useful learning resource as an alternate to traditional lecturer- and tutor-assessments in a highly mathematical core chemical engineering course.
- The class of ~70 chemical engineering students represents a valuable opportunity for a significant sample size.
- Results will be applied with a view to improve Learning and Teaching.

Participation:
- As an enrolled student in **CHEM ENG 3033 & 7052 Applications C** you will be asked to anonymously mark a randomly assigned hardcopy tutorial from a class colleague. The marking scheme will be indicated. Some participants will use as a guide to their marking the idealised solutions of the lecturer-in-charge. You will be asked to complete a follow-up special SELT (*Student Experience of Learning and Teaching*).
- *Participation is voluntary and anonymous.*
- *Participation or refusal to participate will not affect your grades in **CHEM ENG 3033 & 7052 Applications C** now or in the future.*
- *You may withdraw from the study at any time without prejudice to your future grades.*
- Students' marks will not be used for final grade in **CHEM ENG 3033 & 7052 Applications C**.

Contact:
The name, title and telephone numbers of the researcher-in-charge to contact if you have questions or problems is:

Dr K R (Ken) Davey

(08) 83303 5457 (work hours)

kenneth.davey@adelaide.edu.au

THE UNIVERSITY OF ADELAIDE HUMAN RESEARCH ETHICS COMMITTEE

STANDARD CONSENT FORM
FOR PEOPLE WHO ARE PARTICIPANTS IN A RESEARCH PROJECT

1. I, ……………………………………………………*(please print name)* and

   ID, …………………. (*please print student ID*) consent to take part in the research project entitled: **Student peer assessment: A research study in a level III core course of the bachelor chemical engineering degree program**

2. I acknowledge that I have read the attached Information Sheet entitled: **Student peer assessment: A research study in a level III core course of the bachelor chemical engineering degree program**

3. I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.

4. Although I understand that the purpose of this research project is to **improve the quality of learning and teaching**, it has also been explained that my involvement may not be of any benefit to me.

5. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.

7. I understand that I am free to withdraw from the project at any time and that this will not affect my grades in **CHEM ENG 3033 & 7052 Applications C** now or in the future.

8. I am aware that I should retain a copy of this Consent Form, when completed, and the attached Information Sheet.

………………………………………………………… **2 June 2011**
(signature)

WITNESS

I have described to …………………………………………………….

the nature of the research to be carried out. In my opinion she/he understood the explanation.

Status in Project: **Researcher**

Name: **Dr K R (Ken) Davey**………………………………….

……………………………………………………… **2 June 2011**
(signature)

STUDENT'S WORK	ID =
STUDENT ASSESSOR	ID =

Summary Comments

Q8.

Q9.

Q11.

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