Improving student learning through peer marking in a first-year engineering course.

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***Abstract**: The paper reports on an initiative in a first-year engineering course, Electrical and Digital Systems, ELECTENG 101, compulsory for all students. Typically two-thirds of these students subsequently choose a non-electrical-engineering discipline, having no particular interest in electrical engineering. ELECTENG 101 has been seen as a difficult, 'gatekeeper' course. Tutorial attendance declines through the semester: in 2007 and 2008, tutorials were ultimately attended by only about 15% of enrolled students. Aiming to boost tutorial engagement and student achievement, peer-marked assignments were introduced. Students received a small number of marks for doing an assignment, and marking another's. Attendance at tutorial sessions consequently improved radically. Survey results indicated that most students considered peer-marking had made them think more deeply about the material and also about how a solution was communicated. Examination performance improved over earlier years, and there is some evidence that circuit theory concepts were retained better into the following year.*

Background

The first year of the four-year Bachelor of Engineering (Honours) program at the University of Auckland is taught entirely in-house by the Faculty of Engineering. This in-house program, which moves students straight from high school directly into the engineering way of thinking, is very rare internationally: most first-year engineering courses are taught as service courses by academics from mathematics and science departments, with one or two design or hands-on introduction-to-engineering courses providing a taste of "real" engineering (Godfrey et al., 2009). Consequently, the first-year engineering course ELECTENG 101, Electrical and Digital Systems, is compulsory for all 600-plus first-year students. Typically two thirds of these students will subsequently choose a specialization other than electrical and computer engineering at the end of year one. Clearly, many of the students enrolled in ELECTENG 101 may have no particular interest in matters of an electrical nature, and may even have chosen not to study this aspect of physics at high school.

ELECTENG 101 involves students in three lectures and one tutorial each week of the twelve-week semester. As there are two lecture streams, a typical lecture is given to about 300 students. Two lecturers give the lectures, with each of them lecturing both streams for about half the semester. Tutorials are smaller, typically of size 40, and involve several academics. Each tutorial is managed by one academic and one teaching assistant, normally a postgraduate student. In addition to tutorials, informal drop-in clinics are also provided. These take place in a large, open workspace and are staffed by senior students who assist students needing help in mastering the course. Laboratory exercises provide further learning experiences, as do various online resources. While completion of all laboratory exercises is required, there is no attendance requirement for lectures or tutorials. Online assignments (Smaill, 2005) provide early feedback to students about their progress, and this feedback is augmented by that from two written tests.

It is difficult to promote active learning in the large lectures, although this is attempted. The small size of tutorials makes them more amenable to active learning. However, tutorial attendance almost always

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declines through the semester, and this effect has been more pronounced in recent years. For example, in 2007 and 2008, some tutorial streams were, in the latter part of the semester, being attended by only 10% to 20% of the enrolled students: most students did not make the most of the educational opportunities provided. This situation worried the course's lecturers, who were aware that many students perceived the course as difficult and as somewhat of a 'gate-keeper' (Smaill, Godfrey, & Rowe, 2008). Without active involvement in tutorials, too many students were failing to meet the required standard. It was considered that something needed to be done to boost significantly attendance at and involvement in tutorials. The action chosen was the implementation, in 2009, of peer-marking exercises in tutorials. The lecturers were aware of a considerable body of research supporting the efficacy of peer marking. Some of this research is outlined in the following section.

Support for peer marking

The motivating power of assessment has been well-established by research. One study found that by year four only 5% of student time was spent on learning unrelated to assessment (Innis, 1996). Other studies have shown that the assessment system is the main influence on how students structure their learning, determining both their effort and their focus (Miller & Parlett, 1974; Snyder, 1971). Formative assessment is singled out for special mention as a way to improve student learning, with one landmark study asserting: "formative assessment is an essential component of classroom work... We know of no other way of raising standards for which such a strong prima facie case can be made" (Black & Wiliam, 1998b). And again: "significant learning gains lie within our grasp. The research reported here shows conclusively that formative assessment does improve learning. The gains in achievement appear to be quite considerable... amongst the largest ever reported for educational interventions" (Black & Wiliam, 1998a).

The learning improvements delivered by formative assessment persist even when students rather than the instructor carry out the assessment. In fact, in some situations considerable gains can be made by replacing instructor assessment with peer assessment. Gibbs (1999) describes a compulsory second-year engineering course where the format was two lectures and one tutorial a week. At the tutorial students worked on problem sheets which were marked by lecturers and handed back each week. The average exam mark was 55%. Numbers increased and the lecturers no longer had time to mark the problems. The average exam mark went down to 45%. In an effort to restore standards, peer assessment was implemented. Six times during the course, students met and handed in their problem sheets. These were then redistributed randomly with a mark scheme. Students then marked the work they were given and the papers were returned immediately. Marks were not recorded and teachers were not involved at all in this process. Students were required to complete about three quarters of the problem sheets, otherwise they could not complete the course. Everything else about the course remained the same. Amazingly, the average exam mark went up to 75%. Two conclusions may be drawn from the above. First, the weekly problem sheets, when marked, motivated students to actually solve problems and distribute their effort more effectively rather than concentrate it in the period just prior to the final examination. It is also likely that having one's work marked by peers is more daunting than having it marked by some relatively-unknown tutor. However, it is improbable that this in itself would have produced such a large achievement gain. Second, there is a clear benefit from having students actually carry out the marking process. The act of examining a mark schedule and following it gives a fuller perspective than simply doing the problems can give. In marking the problems of other students, the markers would have noticed other ways to do the problems correctly, errors which they made themselves, and errors which they were alerted to avoid. They would also see the care some students took and others did not. They would get a good idea of the standard of work and the effort required to achieve at various levels. In time, the process of marking enables students to internalise the appropriate standards. Once the standards are internalised, students are equipped to be able to monitor the quality of their own work. The importance of this is illustrated by the large lift in achievement that occurred when peer marking was introduced. However, students do not always appreciate the benefit to themselves to be gained by marking the work of their peers: "When students object to self-assessment or peer assessment it is often because they do not understand the importance of internalizing standards in order to be able to supervise one's own work" (Gibbs, 1999). Mafi (1989)

also reported increased student understanding and involvement, together with decreased instructor workload, as a result of implementing peer assessment in civil engineering.

The research question investigated was: "To what extent would peer-marked assignments improve student learning in the first-year electrical engineering course?" The research methodology followed is outlined in the subsequent sections. We report on the method used to implement peer marking, the evidence for success as measured both by performance in ELECTENG 101assessments and performance in a diagnostic test in a subsequent year-two course, and student, tutor and staff surveys. We conclude by addressing possible confounding issues and weaknesses in our methodology.

Implementation of peer marking

ELECTENG 101 has 15 tutorial sessions timetabled per week. About 40 students are allocated to each tutorial group. Each group has a staff tutor (one of eight), who is assisted by one of seven teaching assistants (TAs). In 2009 and 2010 peer-marked assignments were set by the lecturer every two weeks. Students were asked to bring their completed assignment to their next tutorial for peer-marking. They were told they would receive 1% of their course mark for doing the assignment. This included preparing a paper solution for marking, and then marking someone else's script. The 1% was given for taking part in the process, rather than for their answers to the questions. Tutors and TAs were given briefing documents for each marking session, indicating how to present the solution, and how marks should be allocated by the student markers.

Students had to attend tutorials in order to receive their 1%, and the response to this incentive was most gratifying, with near-100% turnouts for tutorials in which marking would occur. In these tutorials, the staff tutor would divide the room in two, and students were asked to exchange their scripts with students in the other half of the room. Students were then asked to mark their details (name, ID) on the script they were about to mark. The staff tutor would then go through the assignment in detail, explaining the correct solution to each of the questions and indicating where marks could be gained and lost. A document camera was used to project details onto a screen. Typically the marking would take about half the allocated period (about 25 minutes). After marking, scripts would be returned to their owners, who were asked to check them quickly, before they were collected up by the TA. It was then the job of the TA to take the scripts away and ensure that each student had participated correctly by providing an adequate script and marking correctly someone else's. Those completing the requirements were given the 1% mark. Scripts were returned at the next week's tutorial, giving an incentive for students to attend that as well. In 2009 a total of 5 peer-marked sessions were held during the 12-week semester, increased to 6 for 2010.

Evidence of success

Initial testing revealed only a small improvement in the academic quality of the 2009 student intake over the intakes of previous years. However, results in the ELECTENG 101 final examination were significantly improved, with a markedly lower failure rate: 5.4% in 2009 when peer-marking was used, versus 10.4% in 2008 when it was not. Results from 2010 are not yet available.

Diagnostic-test results also suggested that the improvement persisted through to the start of the following year at least. Students from the 2008 ELECTENG 101 cohort who subsequently enrolled in the electrical-engineering specialisation in 2009 sat a diagnostic test (based on ELECTENG 101 content) at the start of that (their second) year. For the 120 students who sat, the mean result was 8.42 out of 20 and the pass rate was 47%. Students from the 2009 ELECTENG 101 cohort who subsequently enrolled in the electrical-engineering specialisation in 2010 also sat the same diagnostic test at the start of that year. This time 155 sat, the mean was greatly improved at 11.46 out of 20, and 52% passed the test. This 2010 result was surprisingly good, given that this group contained a number of low-GPA students who were only enrolled in the electrical-engineering specialisation because they had failed to get into their first-choice specialisation. It was considered that, if anything, the 2010 year-two cohort would be weaker on account of these additional students. Instead, the 2010 year-two cohort, who had experienced peer marking, performed better on the diagnostic test than the

2009 year-two cohort, who had not experienced peer marking. The improved diagnostic-test results support the notion that peer marking may have contributed to better long-term retention of fundamental material.

Student feedback

A paper survey was administered (to all tutorial groups) to gauge how the students rated the peer-marking tutorials. Students were asked two questions and also given the opportunity to provide their opinions on peer marking via a free-format question. The results strongly supported the peer-marking tutorials. Of the 429 respondents, fewer than 3% reported (see Table 1) gaining no support for their learning through the peer-marking tutorials. There was strong support (Table 2) for the proposals that the peer-marking exercises made students think more deeply about course material, made them more aware of difficulties encountered by staff in the marking process, and made them think more deeply about how a solution is communicated. The responses indicate that the frequency and time devoted to peer marking was appropriate.

Question 1	
To what extent do you consider that peer-marking supports your learning?	
Not at all	12
A little bit	83
Fairly well	238
Very well	96

Table 1 Student assessment of learning support value of peer marking

Question 2							
Please indicate how much you agree with the following statements, using the following scale: **SA** = strongly agree / **A** = agree / **N** = neither agree nor disagree / **D** = disagree / **SD** = strongly disagree / **DK** = don't know / **R** = refuse to answer							
	SA	A	N	D	SD	DK	R
Peer-marking is done too often	13	48	148	173	49	1	
Marking the papers made me think more deeply about the course material	38	218	113	67	12	4	
I am now more aware of difficulties encountered by staff in the marking process	41	221	119	39	16	9	
Peer-marking made me think more deeply about how a solution is communicated	65	258	92	9	9	1	
The amount of time given in tutorials for marking is about right	66	267	65	32	12	1	

Table 2 Student assessment of peer marking impact

In the free-format section of the survey, the extensive student comments were overwhelmingly in support of the peer-marking tutorials. Many students commented on the usefulness of the tutorials for motivating them to work steadily rather than in bursts:

"Peer marking is an excellent way to motivate students... it is an excellent way for students to keep on track with what's happening in lectures."

"Usually I study for tests/exams the very last day but peer marking makes me have to go through my notes so I actually get my studying done over several weeks (which is good)"

"Peer marking does ensure I keep updated with the course material taught every week."

"Peer marking is a useful way of constantly doing exercises and learning in a relaxed environment."

"It forces people to do tutorial work which aids in the learning process."

Other students commented on the resulting improvement in their understanding and problem-solving ability.

"Very good for when the last week's lectures were unclear."

"It helps to learn and understand what we do in lectures."

"I find it VERY helpful for my learning because now I understand how to solve questions more efficiently."

"It helps to learn and understand what we do in lectures."

"Peer marking was quite helpful because it makes you analyse what your strengths and weaknesses are in the current topic."

Some students saw a benefit in seeing a diversity of approaches to answering questions.

"It's a good system, as it encourages us to learn from a different perspective."

"Good way of looking at more types of questions and seeing both different ways other people approach problems, and how markers approach marking a solution."

"I can compare the solutions made by other people and make corrections where necessary if theirs are more appropriate than mine."

"A good way of learning, as you see how the answer should be done and different ways of doing it."

The two most-common negative comments related to not getting their scripts returned until the following tutorial and not having model answers subsequently posted on the learning-management system we use (CECIL).

"Would be a lot better if we could take our peer marking sheets in the same day that the peer marking is done."

"To get the peer marking sheet back the same date it was done."

"Answers with working posted up on CECIL would be a lot more handy for the PM exercise."

"The answers should be posted on CECIL or maybe handed out after the tutorials."

In addition to the survey conducted by the lecturers on peer-marking, the course itself was subject to an annual course survey (as part of the Faculty of Engineering quality-control processes). This survey provided a wealth of additional extremely positive comments about peer- marking and the course was ranked second-highest in the Part 1 program. Interestingly, the course which achieved the highest ranking was the only other course taken by this cohort of students which used peer-marking in tutorials.

Tutor feedback

Eight staff members were tutors for ELECTENG 101 during 2009 and took part in the peer-marking sessions, each assisted by a teaching assistant. Feedback on the success of the peer-marking tutorials was sought from the staff tutors, who were asked to complete a questionnaire.

100% of staff tutors responding strongly agreed that peer marking appeared to help student learning, and that it increased tutorial attendance.

80% strongly agreed that peer marking made students think more deeply about how solutions are communicated, that student retention of material appeared to be improved by peer-marking assignments, and that marking the papers made the students think more deeply about the course material.

60% strongly agreed that students were motivated by marks given for the peer-marking assignments.

The following additional comments were also made:

"Peer marking definitely improved student test and exam performance. For example, in peer marking, marks were consistently deducted for incorrect units. In the first test students took far more care with units and lost far fewer marks for mistakes involving units than ever before. A massive increase in tutorial attendance was also noted."

"Large turnouts for peer-marked sessions were very noticeable."

"…I am very positive about peer marking. There is only one point I disagree with, namely that students think more about the course material. I cannot confirm this; from my observations there does not seem to be a significant transfer effect. That is, while students become very good at doing the questions they have done in the peer-marking, they are not improving in different questions on related material."

Teaching assistant (TA) feedback

TAs who helped with the peer-marking sessions were also asked for their views on how the tutorials went. Comments were very favourable, and a selection is given here.

"I definitely think for those students that become complacent and stop attending early on, it's a good way to keep them focused, attending and completing some questions relating to the course material. Anything making students do some work can only be positive. So taking that into account I think they definitely learnt more than they usually would have done, when they otherwise would have just waited till the week (day) before the test and realized that in fact the material is rather difficult. For the top students I think it really doesn't make much difference to their learning, but tutorials are not really focused at this group anyway"

"Students seem to be slightly aware that someone is going to have to mark their work and I did witness some students think about how they lay it out and are aware they will lose marks for insufficient working. So hopefully this ended in them constructing better answers in tests and exams."

"The student learning did improve as a result of peer marking exercise as it allows them to know how others think".

"It forces the students to grasp the material at early stage of (the) course which results in better understanding of the course."

"I marked (a) few exams and found that most of the students did write the UNITS of the quantities in (their) solution. It was definitely due to peer-marking exercise."

"I think peer marking exercise is a good practice to do and it adds an intermediate dimension between personal study of a student and the exams (assessments)."

Some TAs did remark that some students were rather selective in their tutorial attendance:

"No doubt about that [student attendance at tutorials improving as a result of the peer-marking exercises]. The attendance was around 90% on the marking day and will drop to 35% to 45% on other days."

"This has a huge impact on the turn-over of students in the class; some students do leave right after the peer-marking exercise. But this also ensures an interaction between students of different academic calibres and is therefore more helpful for struggling students who can see (the) refined solutions of diligent students."

The point was also made that peer-marking exercises should not be over-used:

"I wouldn't do peer marking any more often, as you'd start to affect attendance as people become complacent with peer marking. There also has to be time for the students to get feedback and help with their other work."

Lecturer feedback

In their Course Audit (a compulsory post-course teaching-team reflection document) the course lecturers observed that tutorial attendance in 2009 hit an all-time high, up from the all-time low experienced in 2008. They speculated that this was most likely a direct result of the peer-marking exercises, or at least the associated 1% course credit! The lecturers (both of whom consider tutorial participation to be a very important part of the student learning experience) found the turnaround in tutorial attendance to be most gratifying.

While initial testing revealed only a small improvement in the academic quality of the 2009 student intake over the intakes of previous years, the 2009 cohort of students ultimately achieved significantly more highly, this being borne out by both the examination results and the final grades. Here it should be noted that the final grades depend not only on the final examination but also two tests and two online assignments. In 2008, the failure rate was 10.4% with 15 DNS (did not sit) grades, while in 2009 (following the peer-marking exercises) the failure rate was 5.4% with 9 DNS grades. The percentage of A grades also went up, from 40.3% to 46.5%. The only change in the course from 2008 to 2009 was the introduction of the peer-marking exercises. The diagnostic test sat the following year by a subset of these students (those who subsequently enrolled in the electrical-engineering specialisation) also indicated significantly improved student performance.

Discussion and Future Directions

Isolating the effects of teaching innovations is a complex problem, with many factors contributing to the overall student performance. In order to eliminate possible confounding issues, a number of questions would need to be answered, including the following:

- Did the lecturers simply train the students to perform well in the final examination?
- Was this a more gifted cohort than normal?
- Were the lecturers and tutors simply more effective than usual in 2009?
- Was the exam too easy?

While it is impossible to be totally objective about a course which they themselves teach, the lecturers believe that they didn't train the students, and that the exam was of the same standard as usual. There was evidence, available from university entry scores and from diagnostic testing conducted in the first week of lectures, that this was a slightly more gifted cohort than in the previous two years, slightly confounding the results. A further confounder, believed to have only a small effect, is that with each cycle of this course it is likely that the lecturers and tutors become more adept at helping students master the previously identified difficult concepts.

The student comments align well with reviews of peer-marking published in the education-research literature. Many students commented that the peer marking encouraged them to distribute their efforts more evenly throughout the semester. A large number of students indicated that they gained a deeper

understanding of the technical problems, an improved appreciation of how to communicate their solutions, and insight into alternative correct approaches and of other approaches to avoid.

The lecturers concluded that the peer-marking exercises were very successful and should definitely be retained. They also concluded that some fine-tuning needed to take place. Changes likely to be made are to make the exercises shorter and even more frequent. It is likely that they will be based principally on past exam questions, with the marked exercises returned during the same tutorial and with model answers posted (at the end of each week of peer-marking tutorials) on the learning-management system.

Conclusions

In an effort to boost tutorial attendance and engagement, and student achievement, peer-marked assignments were set in a compulsory first-year engineering course, ELECTENG 101. Students received a small number of marks for doing an assignment, and marking another's. Peer marking took place under the guidance of a staff tutor. Attendance at tutorial sessions improved very significantly during peer-marking sessions. Students were required to interact with the tutorial material both from the perspective of one solving the problem, and also from the perspective of a marker.

Survey results indicated that the great majority of students considered peer marking had made them think more deeply about the material and also about how a solution is communicated. Tutors and teaching assistants noted that peer marking appeared to help student engagement and learning. Examination performance improved over earlier years, and results from a follow-up diagnostic test provide some evidence that circuit-theory concepts were retained better into the following year.

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