AN EVALUATION OF AN EXPERIENTIAL LEARNING INITIATIVE IN A FIRST-YEAR ENGINEERING MATERIALS COURSE

Wayne Hall[a], Stuart Palmer[b], Simon Howell[a], Zia Javanbakht[a] and Nicholas Emerson[c]
Griffith School of Engineering and Built Environment[a], WorkSafe Victoria[b], School of Product Design, University of Canterbury, New Zealand[c]
Corresponding Author Email: w.hall@griffith.edu.au

ABSTRACT

The introduction of experiential learning content into a first-year Engineering Materials (1017ENG) is investigated. The success of 1017ENG is evaluated in the context of an earlier, similar traditional offering of the course (1502ENG). The student experience of course (SEC) evaluation data and student performance in 1017ENG and 1502ENG are compared. Student satisfactions levels are found to be maintained in 1017ENG and the experiential focus results in an overall improvement in student performance. There is no significant difference in the proportions of low-achieving students (those recording a 'Fail' grade) or in the proportions of the highest achieving students (those recording a '7'). The overall improvement in performance arises from the notable differences in the proportions of middle-range of students for the two courses (i.e. in the proportions of students with '4' and '6' grades).

Keywords: Engineering Materials, Experiential Learning, Student Satisfaction, Student Performance.

INTRODUCTION

In 2017, Griffith School of Engineering and Built Environment introduced a new 'common' first-year curriculum across its four-year Bachelor of Engineering (BEng) and related double degree offerings. The curriculum was reinvented to help integrate mathematics, science and computer programming skills in a design and engineering practice framework. The redesign aimed to improve student educational outcomes and engagement, and to improve student retention and progression rates. A detailed rationale for the introduction of the new common first-year curriculum is presented in Howell et al.[1].

The BEng programme offered at Griffith's Gold Coast campus includes the following specialist majors:
· Mechanical Engineering
· Civil Engineering
· Electrical and Electronic Engineering.

The first-year curriculum now offers a modern educational experience that draws on traditional learning and teaching practices integrated with the learning-by-doing model initially pioneered by Dewey[2] and more recently the concept of experiential learning developed and articulated by Kolb[3].The School's implementation of these changes at first year level means that the learners have limited experience of the 'routine' of a traditional university course. Accordingly, there is no standardised framework from which to benchmark their study practices and this can help promote an environment in which genuine experimentation can flourish. The result is a curriculum which retains some traditional components but offers a greater emphasis on hands-on practice underpinned with science and mathematics[1], and learning (and assessment) activities that place an explicit focus on student reflection.

A mix of traditional, partially- and fully- experiential learning courses are offered. Traditional ('chalk and talk') courses provide formal lectures, tutorials and laboratory-practical classes, whilst a course defined as partially-experiential retains some traditional components such as lectures, but these tend to be integrated with small embedded practical activities or projects. In a fully-experiential learning course, the assessment is mostly continuous (often project-based) and there is no final examination[1]. For an example of what could be defined as a partially-experiential learning course see reference[4], and for an earlier attempt at introducing a fully-experiential course into the first-year curriculum, see Palmer and Hall[5] and Hall et al.[6].

In this paper, we aim to evaluate the success of the introduction of experiential learning content in an Engineering Materials course. A understanding of materials science and engineering concepts is essential for an engineering practitioner and this content is therefore a core element in any materials design education[7-9]. Here, the move towards inclusion of experiential learning content in Engineering Materials (1017ENG) is evaluated in the context of an earlier, traditional (i.e. more didactic) offering of a similar course (1502ENG) that has similar technical learning outcomes and topic content.

1502ENG/1017ENG ENGINEERING MATERIALS

1502ENG Engineering Materials was first offered in 2010 but remained unchanged from 2011 until it was reinvented as 1017ENG in 2017 and offered twice per year (semi-annually) in the first and third trimesters (referred to as T1 and T3, respectively). Herein, only the findings from the unchanged 1502ENG course and the reinvented 1017ENG course are considered. Moreover, in 2016 (prior to the transition to 1017ENG) 1502ENG was temporarily convened by another academic not previously involved with the course and hence, in order to provide a fair and balanced comparison, that year's data is excluded from the current study.

The traditional offering (1502ENG) provided 2 hours of formal lectures per week and a 1 hour tutorial class. In addition, two laboratory-practical classes, each 2 hours in duration, were used to reinforce the theoretical content presented in lectures and tutorials. The laboratories were step-by-step activities linked to course content, rather than project activities. Four elements of assessment were used:

- In-class test – 15%;
- Laboratory assessments (technical laboratory reports) –15%;
- Group assignment (written report) – 10%; and
- Final examination - 60%.

To pass 1502ENG, students were required to attain 50% overall as well as pass a hurdle requirement of achieving at least 40% in the final examination.

Understanding engineering materials and the knowledge of how to apply them requires a balance of a fundamental knowledge of material theory and behaviour, and a somewhat sensorial[10] understanding of the materials' tactual qualities. As with other changes in educational design, the course team considered that the move from 'traditional' to 'experiential' learning would help to foster the learner's fundamental understanding, embedding deeper knowledge than is obtained through examinations and their corresponding promotion of rote-learning[11, 12].

The reinvented Engineering Materials course (1017ENG) retains similar learning outcomes to the traditionally-taught version of the course (1502ENG), as well as a similar lecture and tutorial timetable to teach the similar topic content, i.e. 2 hours of lectures per week and a 1 hour tutorial. However, in contrast to the original, 1017ENG provides on-going concept quizzes as well as three small (investigative) project activities that require 2 hours per week of predominantly student-led activities for 8 weeks. These projects are designed as experiential learning activities but are also grouped to maximise student engagement[13]. The change from individual exams to group-based experiential projects (and the corresponding assessments) are therefore the main difference in learning design. The revised assessment plan is:

- On-line concept quizzes (x5) – 20%;
- Small embedded (group) projects– 70%; and
- Group assignment (research-based) – 10%.

Again, to pass 1017ENG, students were required to attain 50% overall as well as a hurdle of at least 40% overall in the concept quizzes.

A summary of the structure and assessment items for 1502ENG and 1017ENG are provided in Table 1.

Table 1. Course learning design for 1502ENG and 1017ENG.

Course	Course Structure	Assessment Items	Grade Criteria
1502ENG	Lectures: 2 hours/week. Tutorials: 1 hour/week. Laboratories: 2 x 2 hours.	In-class test – 15%. Laboratory assessments (technical laboratory reports) –15%. Group assignment (written report) – 10%. Final examination - 60%.	To be eligible to pass, students must achieve 50% of the total mark, as well as ≥ 40% in the 'final examination'.
1017ENG	Lectures: 2 hours/week. Tutorials: 1 hour/week. Project activities: 8 x 2 hours.	On-line concept quizzes (x5) – 20%. Small embedded (group) projects– 70%. Group assignment (research-based) – 10%.	To be eligible to pass, students must achieve 50% of the total mark, as well as ≥ 40% in the 'On-line concept quizzes'.

METHODOLOGY

The move towards more experiential learning content in Engineering Materials (1017ENG) is evaluated in the context of the earlier, more traditional offering of the course (1502ENG). The Student Experience of Course (SEC) instrument and the cohort performance in 1017ENG and 1502ENG are compared to evaluate the success of the partially-experiential initiative. Multiple offerings of both the traditional and new course are reviewed in the analysis.

If student evaluation data are to be used effectively, it is important that the rating results be communicated in a manner that provides a sound basis for rational decision making[14]. There is a need to take into consideration the known systematic influences on student evaluation data[15, 16]. One long-standing model of providing guidance on the interpretation of student evaluation is the Rating Interpretation Guides (RIGs) system[14, 17, 18]. Although the details vary, the essential element of a RIGs system is the provision of a norm-based set of benchmarks against which obtained student evaluation ratings can be meaningfully compared. Such benchmarks are based on a set of courses that are similar to the target course in relevant respects. The Griffith University SEC data are reported with a set of benchmark comparison mean item ratings based on the 25 per cent, 50 per cent and 75 per cent quartile mean item ratings for a group of comparable courses (from the same Faculty group and of a similar sized enrolment). For the purpose of reporting of SEC results, the course enrolment size bands that are used to determine which group a course belongs to for benchmark comparisons are: less than 21; 21-50; 51-200; and, 200 or greater students. Using appropriate comparisons based on those cohorts with comparable enrolment size, we compare the student experience reported by students in the revised 1017ENG and traditional 1502ENG courses.

STUDENT EXPERIENCE. The Griffith University SEC instrument contains six numerical scale items that are used to assess the student experience, course improvement and staff performance process. Here, SEC data is used as a basic tool to compare the student perception of the two different course designs. In the instrument, the first five items relate to specific aspects of the course (for example, SEC1 – This course was well-organised) whilst the sixth provides an overarching question about the course, i.e. SEC6 - Overall I am satisfied with the quality of this course. The student responses are based on a five-point Likert scale that measures their level of agreement with each statement: Strongly Agree (=5), to Strongly Disagree (=1). In the context of this paper, the focus is only on the overarching question, but consideration is (of course) given to the influence of class size on student perception[15]; 1017ENG tends to have smaller classes sizes than 1502ENG, especially in the smaller T3 offering where the cohort size is $\leq$20% of the T1 enrolment. Previous research has shown that student evaluation of teaching 'overall rating' survey items provides a reliable single-item measure of "overall satisfaction with quality" that can be used to benchmark changes in course learning design[19]. For further information on the Griffith University SEC instrument is published elsewhere[20, 21].

The known influence of class size on student perceptions[22] adds significant complexity to any comparison between SEC data for 1017ENG and 1502ENG. To address this, a comparison can therefore only be made for similar size cohorts. Based on the SEC benchmark course enrolment bands noted above as a guide it can be seen that all of the offerings of 1502ENG had an enrolment greater than 200, whereas only the 2017 T1 offering of 1017ENG had an enrolment greater than 200. Thus, only these similar size (large) cohorts for 1502ENG and 1017ENG can be strictly compared and analysed. The SEC6 results for all offerings of 1502ENG were pooled and then compared to the SEC6 results for the 2017 T1 offering of 1017ENG (the only large cohort) using a one-way analysis of variance (ANOVA). The ANOVA analysis was used to test for significant differences in the mean SEC6 overall satisfaction ratings.

STUDENT PERFORMANCE. Student grades for all offerings of each course (1502ENG and 1017ENG) were 'pooled' as there was consistency of the learning design in both courses during the respective periods under consideration. To consider the possibility that class size effects may influence the grade distribution for 1017ENG (as they are known to do for SEC scores), the results for 1017ENG in T1 and T3 were separately pooled, and then the proportions of final grades for T1 and T3 were compared using a Chi-squared test. As no significant difference in the grade distributions were noted for the separately pooled T1 and T3 results at a significance level of $p < 0.01$, the total pooled results for both academic sessions (T1 and T3) were considered appropriate for comparison to the 1502ENG pooled results. These total pooled results for 1017ENG were compared against the pooled distribution of grades for 1502ENG using a Chi-squared test, again with a statistical significance level of $p < 0.01$.

The Chi-squared test is an omnibus/overall test – here it can indicate that the two course grade distributions are significantly different, but it does not say anything about the difference in the proportions of each grade category between the two courses. It is possible to perform post hoc pairwise comparisons of proportions between individual grade categories ('Fail', '4', '5', '6' and '7') for each course. For post hoc pairwise tests, it is standard to require a stricter level of significance to account for the multiple tests rolled up in the omnibus test. A common adjustment to the significance level for post hoc tests is the Bonferroni correction, which divides the original target significance level by the total number of possible pairwise tests in the omnibus test (here ten). However, as the number of categories increases, the Bonferroni correction becomes unrepresentative of the number of pairwise tests likely to be actually performed and unrealistically onerous. Here, we used the modified Bonferroni correction proposed by Keppel[23], that multiplies the original target significance level by the degrees of freedom in the omnibus test (here four) and then divides by the total number of possible pairwise tests in the omnibus test (here ten). So, the target significance level for the post hoc pairwise comparisons of proportions between individual grade categories for each course is $p < 0.004$.

RESULTS AND DISCUSSION

STUDENT EXPERIENCE. Table 2 provides an overview of the student responses to SEC6; mean scores and the corresponding standard deviations for both the traditional course (2010-2015 inclusive) and the new partially-experiential offering (2017-2019), alongside the cohort sizes. The student enrolments are relevant in the context of the study as student perceptions are known to be influenced by course-related factors such as class sizes[15, 22]; students tend to prefer smaller class sizes and this is typically reflected in the evaluation scores reported. Figure 1 shows the SEC association with cohort size.

Table 2. Student satisfaction (SEC6) and class sizes for 1502ENG and 1017ENG.

Year	Course	SEC6 – mean (and standard deviation)	Cohort size
2011	1502ENG	4.3 (0.72)	228
2012	1502ENG	4.3 (1.01)	280
2013	1502ENG	3.9 (0.80)	345
2014	1502ENG	4.2 (0.84)	306
2015	1502ENG	4.1 (0.81)	297
2017 (T1)	1017ENG	4.2 (0.78)	240
2017 (T3)	1017ENG	4.7 (0.65)	34
2018 (T1)	1017ENG	4.5 (0.62)	180
2018 (T3)	1017ENG	4.7 (0.47)	36

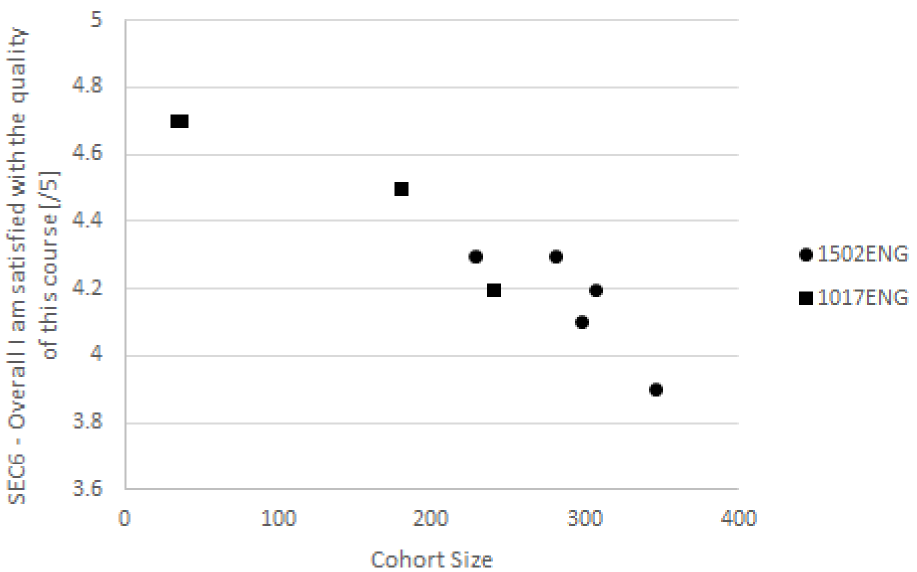

Figure 1. SEC association with cohort size for 1502ENG and 1017ENG.

The SEC scores for 1017ENG and 1502ENG both show high levels of student satisfaction. If each cohort is considered individually, there appears to be a general negative association between SEC6 mean rating and cohort size in Figure 1. This association was also observed previously for different sized course enrolments for 1502ENG (only) over a different time period[22]. However, if we only focus on the large cohorts (for course enrolments above 200, as mentioned earlier) and compare the two courses, the results show no significant difference between the SEC6 mean ratings for 1017ENG and the pooled data for 1502ENG. The pooled SEC6 data for 1502ENG and the SEC6 data for 2017 T1 offering were tested for equality of variance and found to not be significantly different – Levene's test $F(1, 632) = 0.368$, $p = 0.545$. This means that a standard one-way ANOVA could be applied. The results of a one-way ANOVA comparison of the pooled SEC6 data for 1502ENG (mean rating 4.18) and the SEC6 data for 2017 T1 offering of 1017ENG (mean rating 4.25) showed no significant difference in mean student rating for overall quality of the two versions of the large course offering – $F(1, 632) = 0.5$, $p = 0.48$. This suggests that students generally perceive both versions of the larger course offerings to be similar in their quality.

STUDENT PERFORMANCE. In terms of overall academic performance, students enrolled on 1017ENG tended to perform better than those enrolled in the earlier offering (1502ENG). Table 3 provides a breakdown of the grade distribution for 1502ENG, whilst Table 4 presents the equivalent 1017ENG course data. Note that the grade category and trimester of offer for 1017ENG was analysed using a Chi-squared test $X^2(4, N = 490) = 8.762$, $p > 0.062$. The distribution of grades were found to not be significantly different, enabling pooling of the T1 and T3 data.

Table 3. Student performance (grade distribution) in 1502ENG.

		PASS GRADES			
YEAR	FAIL	4	5	6	7
2011	44	74	58	35	17
2012	70	151	48	7	4
2013	22	81	130	83	29
2014	67	148	65	22	4
2015	51	109	93	36	8
PERCENTAGE	17.4	38.7	27.1	12.6	4.3

Table 4. Student performance (grade distribution) in 1017ENG.

		PASS GRADES			
YEAR	FAIL	4	5	6	7
2017 (T1)	45	98	60	28	9
2017 (T3)	2	14	8	8	2
2018 (T1)	13	20	58	72	17
2018 (T3)	4	18	10	4	0
PERCENTAGE	13.1	30.6	27.8	22.9	5.7

Figure 2 presents the distributions of grades for the pooled results for 1502ENG and 1017ENG. Using a Chi-squared test, the result for the overall cross tabulation of grade category and subject was $X^2(4, N = 1946) = 38.150$, $p < 1.4\text{x}10^{-7}$; the overall grade distributions were significantly different between 1502ENG and 1017ENG. Considering post-hoc pairwise comparisons between individual grade categories and subject, as noted above, the target statistical significance level, following adjustment was $p < 0.004$. For the grade category of 'Fail', the proportions for 1502ENG and 1017ENG were not significantly different $X^2(1, N = 318) = 5.154$, $p > 0.023$. This was also the case for the grade categories '5' ($X^2(1, N = 530) = 0.089$, $p > 0.765$). and '7' ($X^2(1, N = 90) = 1.762$, $p > 0.184$). In contrast, for the grade category of '4', the proportions for 1502ENG and 1017ENG were significantly different $X^2(1, N = 713) = 10.247$, $p < 0.002$. This significant difference was also true for the grade category of '6' ($X^2(1, N = 295) = 30.174$, $p < 4.0\text{x}10^{-8}$).

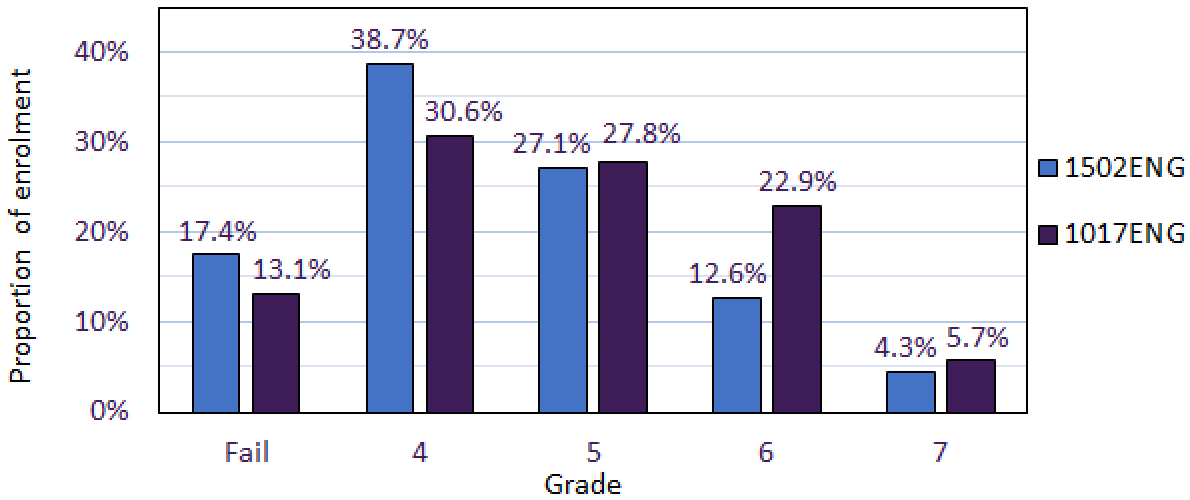

Figure 2. Grade distribution for the pooled results for 1502ENG and 1017ENG.

The course redesign has maintained high levels of student satisfaction and significantly changed the grade distributions. In terms of 1017ENG there is a reduction of the proportion of 4 grades, and an increase in the proportion of 6 grades compared to 1502ENG. This correlates to an overall increase in student performance in 1017ENG. Moreover, the distribution of grades for 1017ENG is much more symmetrical than the distribution of grades for 1502ENG. Treating the grade categories as an ordinal variable, we can show that the skewness for the 1502ENG distribution is 0.49, and that the skewness for the 1017ENG distribution is 0.13. A distribution with a skewness close to zero indicates a more symmetrical distribution, whereas a larger positive value of skewness indicates here a distribution for 1502ENG that is skewed towards lower grades. Since the main course learning design change was the move towards three small projects and small on-going quizzes (as described in corresponding revised assessment plan – see Table 1) it is suggesting here that this move towards a partial-experiential learning course has resulted in better student outcomes overall. One interpretation of the results might be that the new partially-experiential course does not necessarily improve the performance of less able students ('Fail' students) or hinder the highest performing students focusing on 'mastering' the course (those that achieve a '7'), but tends to improve the middle-range students ('4', '5' and '6').

CONCLUSION

The introduction of experiential learning content into a first-year Engineering Materials course has proven successful. Student satisfactions levels have been maintained whilst also providing an overall improvement in student performance. The SEC analysis of 1017ENG indicates the high level of student satisfaction 1502ENG has not been compromised. In contrast, the move towards a partially-experiential course (1017ENG) has resulted in a significantly different grade distribution. Overall, students enrolled in 1017ENG performed better than those enrolled in the earlier traditional offering (1502ENG). Whilst there was no significant difference in the proportions of low-achieving students (those recording a 'Fail' grade) or in the proportions of the highest achieving students (those recording a '7'), there was differences in the proportions of middle-range of students for the two courses (i.e. the proportions of students with '4' and '6' grades).

ACKNOWLEDGEMENTS

The authors would like to acknowledge the useful comments received during the manuscript review process. The comments have undoubtedly improved the quality of this submission.

References

1. S. Howell, W. Hall and N. Emerson, 'Implementing an Integrated First-Year Engineering Curriculum with Mixed Teaching Approaches'. ASEAN Journal of Engineering Education, 4 (1), pp. 1-10 (2020).

2. J. Dewey, 'Experience & Education'. Kappa Delta Pi, New York, NY, 1938.

3. D. A. Kolb, 'Experiential Learning: Experience as the Source of Learning and Development', Prentice-Hall, Inc., Englewood Cliffs, N.J, 1984.

4. P. Woodfield, W. Hall and G. Tansley, G, 'Implementation of an Embedded Project-Based Learning Approach in an Undergraduate Heat Transfer Course', Australasian Association for Engineering Education Conference (AAEE2015), 2015, Geelong, Australia.

5. S. Palmer and W. Hall, 'An evaluation of a project-based learning initiative in engineering education', European Journal of Engineering Education 36 (4), pp. 357-365 (2011).

6. W. Hall, S. Palmer and M. Bennet, 'A longitudinal evaluation of a project-based learning initiative in an engineering undergraduate programme', European Journal of Engineering Education 37 (2), pp. 155-165 (2012).

7. M. Ashby, H. Shercliff and D. Cebon. 'Materials: Engineering, science, processing and design'. Oxford: Elsevier, 2007.

8. O. Pedgley, 'Invigorating industrial design materials and manufacturing education', METU Journal of the Faculty of Architecture, 27(2), pp. 339–360, 2010.

9. V. Rognoli and M. Levi, 'How, What and where is it possible to learn design materials?', In P. Lloyd, N. Roozenburg, C. McMahoon & L. Brodhurst (Eds.), Proceedings of the changing face of design education (pp. 647–654). Delft: Delft University of Technology, 2004.

10. S. Parisi, V. Rognoli and M. Sonneveld, 'Material Tinkering. An inspirational approach for experiential learning and envisioning in product design education'. The Design Journal 20 (sup1), S1167-S1184 (2017).

11. C. Girvan, C. Conneely and B. Tangney, 'Extending experiential learning in teacher professional development'. Teaching and Teacher Education 58, pp. 129–139 (2016).

12. W. Rodgers, J. Simon and J. Gabrielsson, 'Combining experiential and conceptual learning in accounting education: A review with implications'. Management Learning 48 (2), pp. 187–205 (2017).

13. C. Winsett, C. Foster, J. Dearing and G. Burch. ‘The impact of group experiential learning on student engagement’. Academy of Business Research Journal, 3, pp. 7-17 (2016).

14. M. S. Lemos, C. Queirós, P. M. Teixeira and I. Menezes, ‘Development and validation of a theoretically based, multidimensional questionnaire of students’ evaluation of university teaching’. Assessment & Evaluation in Higher Education, 36 (7), pp. 843-864 (2011).

15. A. P. Rovai, M. K. Ponton, M. G. Derrick and J. M. Davis, ‘Student evaluation of teaching in the virtual and traditional classrooms: A comparative analysis’, The Internet and Higher Education, Vol. 9 (1), pp. 23-35 (2006).

16. C. Smith, ‘Building effectiveness in teaching through targeted evaluation and response: connecting evaluation to teaching improvement in higher education’. Assessment & Evaluation in Higher Education, 33 (5), pp. 517-533 (2008).

17. R. Neumann, ‘Communicating Student Evaluation of Teaching Results: Rating Interpretation Guides (RIGs)’. Assessment & Evaluation in Higher Education, 25 (2), pp. 121-134 (2000).

18. S. Palmer and C. Smith, ‘Updating RIGs: including the systematic influence of online study on student evaluation of teaching’. Educational Research and Evaluation, 19 (1), pp. 77-90 (2013).

19. P. Ginns and S. Barrie, ‘Reliability of single-item ratings of quality in higher education: A replication’, Psychological Reports, 95(3), pp. 1023-1030, 2004.

20. W. Hall and S. Palmer, ‘Student Opportunities in Materials Design and Manufacture: Introducing a new Manufacturing with Composites Course’, Journal of Materials Education, 37 (3-4), pp. 155-168 (2015).

21. S. Palmer and W. Hall, ‘Using qualitative student evaluation data to illuminate quantitative scale item ratings: seeing beyond the numbers’, Australasian Association for Engineering Education Conference (AAEE2019), 2019, Brisbane, Australia.

22. S. Palmer and W. Hall, ‘The impact of increasing course enrolment on student evaluation of teaching in engineering education’, Australasian Journal of Engineering Education 20 (1), pp. 31-40 (2015).

23. G. Keppel, Design and analysis: A researcher’s handbook, 3rd ed.; Prentice-Hall: New Jersey, 1991.