Evaluation of the assessment weightings for individual outcome-based projects by final year engineering undergraduates

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ABSTRACT: Research Project-Based (RPB) assessment should be valid, reliable and socially acceptable in that it must not offend students under it, and must also be trusted and esteemed by those who have to act upon it. As the assessment component is an important issue, this study is aimed at describing the evaluation and development of outcome-based project assessment weighting factors by relating the subject assessment results and students' overall academic performance. In particular, weighting factors for three deliverables commonly included in a RPB subject in the Department of Building Services Engineering at the Hong Kong Polytechnic University, ie project portfolio, presentation and individual written report, were determined by maximising the correlation between the RPB subject marks and students' overall academic performance in terms of Grade Point Average (GPA). In this study, as the weighting factors of the assessment sub-components played an important role in determining the final course marks, they must be carefully established and examined by a panel of experts before launching a course. Determining the optimal method for assessment is beneficial to both students and facilitators. It can provide a consistent and objective measure of students' performance.

INTRODUCTION

Assessment is a major component of outcome-based learning for students' achievements. It serves two major areas; firstly, in the realms of certification, diagnosis, improvement of learning outcomes and teaching processes; secondly, in accountability, evaluation, and the motivation of students and facilitators. The Department of Building Services Engineering (BSE), established in 1981 at Hong Kong Polytechnic University (PolyU), Hong Kong, People's Republic of China, is a major educational unit in Hong Kong and offers a number of academic programmes at the sub-degree, degree and postgraduate levels in the discipline of building services engineering.

The PolyU has taken a major, strategic initiative to revise the curricula of its academic programmes. This curriculum revision was conducted in response to the recent directives from University Grant Council (UGC) and in accordance with the University's mission to achieve excellence in professional education. One of the objectives is to develop a stronger alignment between the methods of student assessment and the intended learning outcomes. In addition, given the recent role statement as defined by the UGC, it is clear that the University should strive to provide high value-added education that leads to the development of well-rounded students with professional competences. This is in fact a mission that we have long held and have been explicitly committed to with the formulation of strategic objective plans. The BSE's undergraduate programmes have been revised to adopt an outcome-oriented model with the requirements of a clear articulation of the intended learning outcomes, and designing teaching and assessment methods that align with the intended outcomes [1].

The final year Research Project Based (RPB) subject in the curriculum of the academic programmes at the degree level is a major intended student outcome that acts as a *vehicle* to drive students to develop the skills and abilities to execute a research project. Upon successful completion of the subject, students should be able to adhere to imposed deadlines and various requirements; keep an organised record of daily activities; manage time appropriately for the execution of the research paper; solve problems and make sensible decisions regarding BSE systems; carry out applied research in a critical manner through adequate planning, the development of appropriate methodology and the selection of suitable equipment/computer software; follow standard procedures to conduct site surveys or borrow equipment; operate equipments safely; collect and critically evaluate data and information related to BSE; communicate in written reports, as well as in visual and oral presentations, the progress and final outcome of the study clearly and concisely; plan the development of a research paper in a thorough manner; and write a research paper analytically.

Being the main tool for the indication of students' academic performance, assessment becomes a major concern for both facilitators and students. It is important because it allows for a comparison to be made among students within a class, across different classes of various modes of study and, to some extent, across the years. The comparisons are only relevant if students were assessed by the same standards. Otherwise, students' grades may only reflect their evaluator's personal opinions towards them. Therefore, the consistency of assessment by the evaluators is particularly important.

With the help of a well-defined mechanism to assess students' performance, evaluators will be able to evaluate students more objectively. In other words, a precise procedure in student assessment serves to minimise the subjectivity of judges during evaluation. The weighting factors of the assessment components for these subjects must be determined carefully so that students' performance can be truly reflected by the final subject marks. Determining the appropriate weighting factors for the RPB subjects is difficult and requires professional

judgements from experienced educationists and industrial advisers, as well as feedback from BSE graduates.

The purpose of this study is to develop a well-defined measurement of assessment for the RPB subject students. This will not only ensure the objectivity and consistency of the assessment, but will also increase the efficiency in the process of evaluation. Given that the assessors for each course may vary from year to year, this will minimise the inconsistency due to subjective judgements. As a result, the comparisons of students' grades, across different classes and years, become meaningful and relevant.

THE RESEARCH PROJECT-BASED (DBP) SUBJECT

A research project is undertaken by students with the aim of developing their skills and abilities to independently undertake a major piece of investigation work in a selected specialist subject area. The research is conducted over two consecutive semesters in the BEng (Hons) programme. Students in this stage of study are subject to assessments at the same standard. Therefore, there is only one syllabus for this subject offered to various modes of study, and the way in which the subject is structured and managed to realise the subject aims, as well as the assessment methods that are adopted, as described in the syllabus, are applicable to all students [2].

The research work should be related to, and integrated with, the student's academic studies and is meant to complement the design project work in the programme. It is intended to allow students to develop and practise research skills. The nature of the work is similar to the type of investigation sometimes required in professional practice. Students can propose projects themselves. They are required to take full account of the facilities, resources and opportunities available in the Department or elsewhere. For example, a part-time mode student may be supported by his/her employer's organisation, which will receive benefit from his/her study. A sandwich mode student, who received training on mechanical plant operation and maintenance during his/her study, may opt for a project that requires access to mechanical plants.

The implementation of RPB subjects requires a significant amount of resources, such as equipment, input from supervisors and time for assessment of various deliverables of the project works [3][4]. In order to ensure the consistency of assessment, one must determine the optimal set of weighting factors for the assessment sub-components commonly included in a RPB subject, namely presentation, project file and project report. This study suggests an approach in which the optimal set of weighting factors could be determined by maximising the correlation between the students' final RPB subject marks and their overall academic performance. The academic results of students in academic programmes at degree levels in the Hong Kong Polytechnic University's BSE Department (see Table 1) were used for testing the approach in order to determine the optimal set of weighting factors.

Project Management

Academic leadership for the research project is provided by the subject examiner and assisted by a team of academic staff members with sound research experience. The subject examiner is responsible for overall planning, coordination and assessment, including rationalising assessment marks between groups.

Students are divided into groups of approximately eight. A group coordinator manages each group. This group coordinator is responsible for convening weekly meetings of the group, and meeting with individual students for the purposes of advising, monitoring and assessing.

METHODOLOGY

The subject marks of students enrolled in the RPB programme of the BSE Department were used for data analysis in this study. Each student's final RPB subject mark and the mark of each individual assessment sub-component were compared with the student's Grade Point Average (GPA). A GPA is an average score of all the subject grades of a student; therefore, it appropriately reflects the student's overall academic performance. By adjusting the weighting of each assessment component and correlating the resulting final mark with the GPA, the optimal weighting factor of the assessment sub-components can be acquired. Given that the RPB subject mark contributes less than 10% to each student's GPA, they are assumed to be independent in this study.

There are N individual assessment sub-components for the outcomes, a_i, in the subject, namely: presentation, project portfolio (file) and project report. In addition, each sub-component corresponds to a weighting factor, w_i, which indicates its relative importance in calculating the final subject mark M_s [5]. This is as follows:

$$M_s = \sum_{i=1}^{N} w_i a_i \quad ; \sum w_i = 1 \qquad (1)$$

In this study, the optimal set of weighting factors would ensure that the collective students' ranks by the subject mark M_s are statistically similar to their collective ranks by the GPA. Since the difference, d_j, between these two rankings of a student j is a function of N weighting factors, w_i, it can be minimised at a specific set of weighting factors w_i by,

$$\frac{\partial(\sum d_j^2)}{\partial w_i} = 0 \quad ; i = 1 \ldots N \qquad (2)$$

Table 1: Final year research project based (RPB) subject.

Academic Programmes (Model of study/Funding source/Award)	RPB Assessment results* (Grade Point)		
	Average	Highest	Lowest
Full-time/government-funded/BEng	3	4	2
Part-time/self-funded/BEng	3	4	1.5
Full-time/self-funded/BEng	3	4	2
*>3.6: excellent; 2.74-3.6: very good; 1.75-2.74: satisfactory; <1.75: unsatisfactory			

In order to determine an optimal set of weighting factors for the sub-components, the correlation between students' rankings by the subject marks and their GPA is maximised. This correlation is studied using a rank correlation. The average was assigned for a rank associated with a tied observation.

Provided that the number of ties is relatively less than the number of sampled students, the correlation test is an appropriate method. In this study, there were minimal cases for ties among the collected subject marks and GPA. Therefore, the Spearman rank correlation r_s could aptly indicate the correlation between these two rankings:

$$r_s = 1 - \frac{6\sum d_i^2}{n^3 - n} \tag{3}$$

In addition, a test statistic was carried out to indicate the statistical significance of the correlation:

$$Z = r_s\sqrt{n-1} \tag{4}$$

On the other hand, Kendall's rank correlation coefficient can also indicate the rank correlation in a sample group as follows:

$$r_K = \frac{K}{n(n-1)/2} \tag{5}$$

where, K is the sum of n(n−1)/2 counts for:

$$K = \sum_i \zeta_i \tag{6}$$

$$\zeta_i \begin{cases} 1 & ;\lambda > 0 \\ 0 & ;\lambda = 0 \\ -1 & ;\lambda < 0 \end{cases} \tag{7}$$

$$\lambda = \left(\phi_{1,i+1} - \phi_{1,i}\right)\left(\phi_{2,i+1} - \phi_{2,i}\right) \tag{8}$$

where, ζ and λ are dummy variables, ϕ_1 and ϕ_2 are the students' subject mark and GPA, respectively.

For cases in which there are relatively more n than ties, an approximate standard normal test statistic of significance is given by:

$$t = \frac{K}{\sqrt{n(n-1)(2n+5)/18}} \tag{9}$$

RESULTS AND DISCUSSIONS

Students of the subject can be classified into three sample sub-groups according to the three modes of study as follows:

- Full-time Bachelor of Engineering;
- Part-time Bachelor of Engineering;
- Self-funded Bachelor of Engineering.

The assessment results of these students ranged from D+ to A (GPA = 1.5 to 4), with an average grade of B (GPA = 3). The correlation between the students' final subject mark and their GPA was 0.490 (for existing weighting) and 0.504 (for optimal weighting) with a p-value<0.001. Correlations using both the existing and optimal set of weighting factors are presented for purposes of comparison. As can be seen, both have a positive correlation and are statistically significant. Moreover, it is evident that the optimal set of weighting factors yields a relatively stronger correlation between the RPB subject mark and the GPA of the student.

The optimal set of weighting factors yields the highest correlation among the possible combinations of the weighting factors of the sub-components. Therefore, it serves to maximise the correlation between students' subject mark and GPA. In this study, the optimal set of weighting factors varies among the three sample groups, as shown in Table 2. Nevertheless, they all yield the maximum r_s and r_k. Whether the three sample groups were evaluated separately or together, using the optimal set of weighting factors increased the correlation. Both the Spearman and Kendall rank correlations are presented in Table 3.

Table 2: Assessment sub-components for final year RPB subjects.

Assessment Subcomponent a_i (Weighting Factor w_i, %)	Assessment
Presentation (30%)	Each research team presented their project findings to a panel of judges to demonstrate their ability to execute a research programme
Project Portfolio (40%)	Each member reported their project progress to the Group Coordinator at the scheduled meetings with a portfolio that consisted of a record of their work, for example, project notes, site and survey data, summary of equipment, site/system drawings; site/laboratory measurement data, etc
Project Report (30%)	Each member evaluated the collected data and wrote a research paper to report their project findings, which will be evaluated by an assessment panel

Table 3: Optimal set of weighting factors w_i for RPB subject.

θ_i	n_i	w_1, w_2, w_3	r_s (P)	r_k (P)
Existing				
1	44	0.30, 0.40, 0.30	0.477 (0.0011)	0.348 (0.0010)
2	64	0.30, 0.40, 0.30	0.510 (0.0000)	0.366 (0.0000)
3	45	0.30, 0.40, 0.30	0.469 (0.0011)	0.311 (0.0028)
All	153	0.30, 0.40, 0.30	0.490 (0.0000)	0.341 (0.0000)
Suggested: Maximum r_s and Maximum r_k				
1	44	0.45, 0.20, 0.35	0.532 (0.0002)	0.395 (0.0002)
2	64	0.35, 0.45, 0.20	0.523 (0.0000)	0.374 (0.0000)
3	45	0.20, 0.30, 0.50	0.515 (0.0003)	0.351 (0.0007)
All	153	0.45, 0.20, 0.35	0.504 (0.0000)	0.350 (0.0000)

With the existing weighting factors, certain assessment sub-components are comparably more important in the assessment. This is determined by each sub-component's correlation to the students' GPA. The sub-component with a higher correlation may more accurately reflect the student's academic performance. The correlations for the three sample groups are shown in Table 4. The most significant assessment sub-component is different in each sample group. For example, the results suggest assigning a more significant weighting factor to *Project Report* in groups 1 and 3. On the other hand, a more significant weighting factor should be assigned to *Project Portfolio* in group 2.

In this study, it was found that using the optimal set of weighting factors at maximum r_s yields a stronger correlation between students' subject mark and their GPA than using the existing weighting factors. This correlation remains stronger, whether the three sample groups were evaluated individually or collectively. Nevertheless, these correlations using the existing and optimal weighting factors were not entirely different. Both correlation coefficients were around 0.50. This minor difference suggests that the existing set of weighting factors do allow the subject mark to reflect the student's overall academic performance. The results also indicate that the final subject mark can provide a more accurate reflection by slightly altering the weighting factors of the assessment sub-components. This is not surprising as the existing assessment was made by a panel of experts with quality assurance procedures implemented.

It is also important to point out the differences found among the three sample groups. Although all students of the subject were given identical tasks and evaluated with identical criteria by the same panel of judges, the three groups in this study performed differently. The correlations between the students' final subject mark and their GPA varied slightly among these three groups. Furthermore, the most important assessment sub-component of these groups was also different. This suggests that future curricula may include specific training for the subgroups to make up for the differences.

CONCLUSION

Assessment is ubiquitous and inevitable in the world of education. It is a powerful tool that measures students' performance in their studies. If assessment is not conducted properly, the result may distort the truth and misrepresent the students' actual ability.

In this study, students' subject marks in an outcome-based final year project of an engineering undergraduate programme, using the existing weighting factors of the three assessment sub-components, were found to correlate significantly with students' overall academic performance. Nevertheless, in this study, it is argued that an optimal set of weighting factors provided a relatively higher rank correlation. It was also found that the most significant assessment sub-component, using the existing weighting factors, varied among the three sample groups.

In this study, it is evident that the weighting factors of assessment sub-components played an important role in determining the final subject marks. Therefore, they should be carefully determined by a panel of experts before launching a subject. A suggested approach is to maximise the rank correlation between students' subject mark and their overall academic performance. Determining the optimal method of assessment is beneficial to both students and facilitators. It can provide a consistent and objective measure of students' performance. Consequentially, comparisons of students' grades across different modes of study can reflect true differences and not differences in the evaluator's subjective judgement. It allows assessors to strictly follow the developed protocol for assessment, which can optimally reflect students' academic performance.

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Table 4: Correlation of assessment sub-components for the RPB subject.

θ_i	N_i	i	a_i	w_i	r_s (P)	r_k (P)
1	44	1	(a)	0.3	0.424 (0.0042)	0.303 (0.0052)
		2	(b)	0.4	0.272 (0.0741)	0.209 (0.0672)
		3	(c)	0.3	0.459 (0.0017)	0.336 (0.0026)
Subject Result $\Sigma a_i w_i$				-	0.477 (0.0011)	0.348 (0.0010)
2	64	1	(a)	0.3	0.360 (0.0035)	0.257 (0.0042)
		2	(b)	0.4	0.473 (0.0001)	0.369 (0.0001)
		3	(c)	0.3	0.354 (0.0041)	0.249 (0.0062)
Subject Result $\Sigma a_i w_i$				-	0.510 (0.0000)	0.366 (0.0000)
3	45	1	(a)	0.3	0.312 (0.0369)	0.224 (0.0375)
		2	(b)	0.4	0.391 (0.0079)	0.286 (0.0114)
		3	(c)	0.3	0.511 (0.0003)	0.378 (0.0004)
Subject Result $\Sigma a_i w_i$				-	0.469 (0.0011)	0.311 (0.0028)