World Transactions on Engineering and Technology Education
Vol.4, No.2, 2005

Assessment weighting of design project-based (DPB) subjects for engineering education

Ling-Tim Wong, Kwok-Wai Mui & Wah-Tong To

Hong Kong Polytechnic University
Hong Kong, People's Republic of China

ABSTRACT: Any form of Design Project-Based (DPB) assessment should be valid, reliable and socially acceptable in that it must not cause offence to students, and must also be trusted and esteemed by those who have to act upon it. As the assessment component is an important issue of the subject, this study seeks to describe the evaluation and development of project-based assessment weighting factors by relating subject assessment results and students' overall academic performance. In particular, weighting factors for four deliverables commonly included in a DPB subject of the Department of Building Services Engineering at the Hong Kong Polytechnic University, Hong Kong, China, ie verbal progress reports, formal project presentations, written group and individual reports, were determined by maximising the correlation between DPB subject marks and students' overall academic performance in terms of Grade Point Average (GPA). The problem of organising projects for all students was tackled through an attitudinal survey; the assessment results were collected from the past two academic years. This indicated that *formal project presentations* associated with the highest correlation coefficients in all sample groups, while *verbal progress reports* was the lowest.

INTRODUCTION

Assessment is a major contributor to raise standards at universities in terms of teaching, learning and students' achievements. Assessment quality has a significant impact on challenging students to work hard and encouraging teachers to focus on how to improve the learning attitude of individual students [1]. Assessment serves a series of functions, both on the certification, diagnosis, improvement of learning and teaching, and on the accountability, evaluation, motivation of students and teachers [2]. Taught programmes in universities are rationalised on an ongoing basis to guarantee that subject examiners are responsible for reviewing the syllabus and teaching/learning objectives regularly. Externally, programme development is facilitated through comments from other accredited bodies. Active collaboration with the profession, industry, and universities locally and overseas also ensure the cognisance of developments in education.

The Department of Building Services Engineering (BSE), established in 1981 at the Hong Kong Polytechnic University, Hong Kong, China, is a major educational unit in Hong Kong and offers a number of academic programmes at sub-degree, degree and postgraduate levels in the discipline of building services engineering [3]. Design Project-Based (DPB) subjects in the curriculum of academic programmes at the degree and sub-degree levels act as a *vehicle* to drive students to integrate subject knowledge, develop independent study habits and judgements, explore innovative ideas and perform decision-making. The implementation of DPB subjects requires a significant amount of resources, such as specialist teaching space, equipment, input from tutors and time for assessment of various deliverables of the project works [4-7]. The weighting factors of assessment components for these subjects must be determined carefully so that students' performances are truly reflected in their final subject marks. Determining the appropriate weighting factors for DPB subjects is difficult and requires professional judgement from experienced educationalists and industrial advisers, as well as feedback from BSE graduates.

In this article, the authors argue that weighting factors for the four deliverables commonly included in a DPB subject, ie the verbal progress report, formal project presentation, written group report and written individual report, could be determined by maximising the correlation between the DPB subject marks and students' overall academic performance. In particular, the academic performances of students in four academic programmes, θ_1, θ_2, θ_3, and θ_4, shown in Table 1, at the degree and sub-degree levels at the Hong Kong Polytechnic University BSE Department were used as the basis to determine the appropriate weighting factors. The relative importance of assessment components, from the greatest to the least, was also discussed. Finally, a set of new weighting factors for the assessment components of four programmes was suggested and the resultant subject marks were compared with those derived from existing assessment criteria.

DESIGN PROJECT BASED (DBP) SUBJECT

All students in the BSE Department at degree or sub-degree levels are required to complete a number of DPB subjects as a major part of the programme curriculum. A DPB subject targets the development of students' competences as building services engineers in design, installation, operation and maintenance of building services systems in the dimensions of technical justification, environmental awareness and project planning [4]. Upon satisfactory completion of the subjects, students are able to undertake the following: adhere to the imposed deadlines and various statutory requirements; keep well-organised design portfolios of project requirements, calculations, design drawings and sketches, equipment data, field work data, design decisions and other information; acquire the ability to solve problems and make decisions over the range of BSE systems; demonstrate creativity in building services design; acquire analytical ability towards the rationalisation of design alternatives; become familiar with building design processes in collaboration with developers, architects, surveyors and engineers, and acquire experience in building integration and services coordination; verify design performances using advanced design simulation software package and related field work; apply lifecycle costing to analyse cost impact of design option; set a project programme; develop personal, technical and managerial abilities by taking full responsibility for the building services systems in a building; and communicate with others in a clear and concise manner through written reports, project files, drawings and oral presentations.

The objective of advanced design simulation software and related field study is included in order to support building design tasks. Each student is required to use the software and apply the related field study experience. Of particular importance is the student's approach to develop system designs that not only meet usage requirements, but also to take into consideration broader and more general issues, like the business potential of the building, health, safety and convenience of the occupants, impact on outdoor environments, as well as energy efficiency of the systems, from building envelope design to the utilisation of natural resources, like daylight, solar energy, etc. To evaluate the system performance and take account of the local regulations, energy codes and safety codes are also required. Another significant element is the optimisation of the system design and operation efficiency.

Operation

Project work is conducted with students grouped into teams, usually three in a team. Every student is responsible for one of the three major BSE systems, eg electrical, fire and plumbing services, or mechanical service design on the whole building scale, and for all BSE services on one particular floor or zone in the design building to demonstrate his/her skill in the capacity of an all-round building services engineer. Each student takes up the role as a member of an in-house building services design team such that each team will handle a building project and take part in the design process proactively with design tutors and visiting professionals who play the roles of clients and architects. This team approach resembles the division of work and coordination of services among a team of services engineers in the workplace, where individual inputs are assured by specifying individual responsibilities for one of the main services. Interaction with the visiting architects is assured by demanding that student engineers obtain comment and approval on architectural matters from the former.

Feedback can be obtained from all programmes via student questionnaires, regular staff-student liaison meetings, departmental academic advisor (DAA) comments and other informal sources to indicate that students' workload for the design subject is substantial.

Assessment Components

In this study, students produced a number of deliverables of the design project, and an assessment panel judged their works. These deliverables were grouped into four categories regarding the nature of submission, assessment method, resources required and staff involved; they were a verbal progress report, formal project presentation, written group report and written individual report. The appropriate weighting factor for each assessment component was determined by the Departmental Board of Examiners in order to compute the overall DPB subject grade of a student. Table 2 shows the assessment components and the weighting factors of DPB subjects of the four academic programmes listed in Table 1. The reports are as follows:

- *Verbal progress report:* Each student was under close supervision by the tutors to mimic real life situations. Progress monitoring and tutoring was arranged every week on a team basis. In order to avoid the usual slack in the progress of students, a continuous assessment was exercised. In the weekly meeting with the design tutor(s), each student verbally demonstrated his/her performance in the past week for assessment. If the weekly progress was unsatisfactory, the student would be warned, lest he/she might fail the subject at an early stage.
- *Formal project presentation:* Each group was allowed to present their design project and answer questions to at least three academic staff, including outsiders, giving them the opportunity to practice presentation skills and receive feedback. The individual assessments, one per staff with the elements of presentation skills, argument and conveyance of design ideas, and responses to questions, were then rationalised into a single score.
- *Written group report:* A group design report was written in a suitable style for the BSE professionals to read. Students were required to demonstrate their understanding and capability in design and to justify the design alternatives proposed during the design process. The assessment elements here consisted of a design rationale and justification, argument for theme development, quality of schematic diagrams, and use of English.
- *Written individual report:* Each student was required to demonstrate his/her understanding of design by submitting a case study report(s), including design simulation software and specific design task, for assessment. The assessment elements were the same as for the written group report.

METHODOLOGY

In this study, the DPB subject assessment results, including overall subject marks and marks of individual project components, of students in last two academic years in all four academic programmes at the degree and sub-degree levels (see Table 1) in the BSE Department were obtained and compared with the corresponding students' academic performance. A Grade Point Average (GPA) is the average of all subject grades of a student and is a good indicator of a student's academic performance. Since the DPB subject results contributed less than 10% to the GPA of students, the analysis in this study assumed them to be independent.

The DPB subjects consisted of N assessment components a_i, ie verbal progress report, formal project presentation, written group report and individual written report (drawings inclusive), as shown in Table 2. A weighting factor w_i for each component was assigned to represent its relative importance in calculating the overall DPB subject result, M_s,

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

This study proposed that a weighting factor would be selected so that a student's rank by the DPB subject result M_s was similar to his/her rank by the GPA. The difference d_j between these two ranks of a student j is a function of a weighting factor w_i and can be minimised at certain weighting factors w_i by,

$$\frac{\partial\left(\sum d_j^2\right)}{\partial w_i}=0\,; \qquad w_N=1-w_{N-1}-\ldots-w_1 \ \ldots \qquad (2)$$

Alternatively, an appropriate weighting factor could be determined by maximising the correlation between the design project marks and the students' GPAs. This correlation could be studied by a rank correlation and the results would be replaced by their ranks. For a rank associated with a tied observation, the average was assigned.

A correlation test is a good method when the number of ties is small compared to the number of sampled students n. With the collected results represented by the subject grade points and GPA ranging from 0.00 to 4.50, cases for ties were minimal. Therefore, the correlation between the ranks could be indicated by the Spearman rank correlation r_s, where the difference between ranks of the DPB subject result and the GPA of each student would be determined respectively [8-9].

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

A significant correlation is indicated by a test statistic approximated by a normal distribution, ie $Z=r_s\sqrt{n-1}$.

The rank correlation in each sample group with i, i+1, … n students can also be indicated by the Kendall's rank correlation coefficient [8-9]. Here, κ is the sum of n(n – 1)/2 counts, ζ and λ are dummy variables, ϕ_1 and ϕ_2 are the design project mark and the student GPA respectively.

$$r_K=\frac{\kappa}{n(n-1)/2}\,;\ \kappa=\sum_i \zeta_i\,;\ \zeta_i=\begin{cases}1 & ;\lambda>0\\ 0 & ;\lambda=0\,;\\ -1 & ;\lambda<0\end{cases}$$

$$\lambda=\left(\phi_{1,i+1}-\phi_{1,i}\right)\left(\phi_{2,i+1}-\phi_{2,i}\right)\ \ldots \qquad (4)$$

For moderate to large n and a few ties, an approximate standard normal test statistic of significance is give by,

$$t=\frac{\kappa}{\sqrt{n(n-1)(2n+5)/18}}\ \ldots \qquad (5)$$

RESULTS AND DISCUSSIONS

Table 1 summarises the academic results of the DPB subjects for final year and non-final year projects of the four academic programmes in the past two academic years. They were classified into four sample groups θ_j as shown in Table 2, ie final year design project for all bachelor degree programmes θ_1; final year design project for higher diploma programme θ_2; non-final year design project for self-funded bachelor degree programmes θ_3; and non-final year design project government-funded bachelor degree programme θ_4.

The assessment was graded from C to A (GPA = 2 to 4), with an average grade in between C+ and B (GPA = 2.5 to 3). The distribution of the assessment results for the assessment components a_i, using the existing weighting factors w_i, subject results M_s and the GPA of students from the four sample groups θ_j. The results were normally distributed and the overall subject average was slightly higher than the average GPA of all students (θ_1, θ_3 and θ_4), except for the higher diploma programme (θ_2) where similar averages were found.

A scatter plot demonstrated the correlation between the GPA of the students and the subject results M_s; having a positive slope and a significant correlation coefficient ($P < 0.0000$).

The same correlations in the four sample groups were evaluated by the Spearman and Kendall rank correlations with Equations (3) and (4) [8-9]. With the existing weighting factors w_i, the rank correlation coefficients r_s and r_k are shown in Table 2. Positive correlations were found for all assessment components in all DPB subjects of the four programmes and the design project results M_s did correlate with the GPA for all sample groups θ_j (r_s = 0.3-0.6; r_k = 0.2-0.5; $P < 0.002$). It was also observed that the assessment by *presentation* was associated with the highest correlation coefficients in all sample groups, while the one by *progress* had the lowest. Based on the criteria developed for the project-based assessment, verbal progress reports might not be a suitable assessment component with such a high assessment weighting factor. At the same time, individual written reports was more *representative* when compared with written group reports [8-9].

Weighting factors w_i were determined in order to maximise the above correlations, with the results listed in Table 2. They suggest assigning a more significant weighting factor to formal project presentations. Almost all results (except one) suggested that verbal progress reports as a less significant weighting factor. Similarly, a more significant weighting factor should be assigned to individual written report, while a less significant factor should be to given to group written report.

The subject results M_s of all students using existing and adjusted weighting factors w_i were compared, and are shown in Figure 1. It was reported that, with the application of the adjusted weighting factors, the variation of students' subject grades was not momentous. In the four sample groups, only a few students were downgraded by 0.5 in their GPA, ie from A to B+, and a few cases from B+ to C and B to C+. Students who received Grade C remained unchanged. Grades moving downward would be obvious because the subject results, using the existing weighting factors, were higher than the overall GPA.

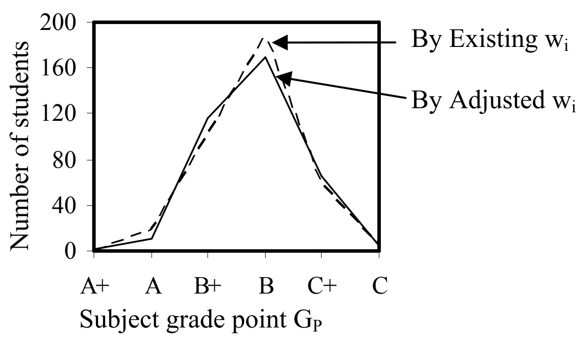

Figure 1: Students' subject grades with different weighting factors for DPB subjects.

CONCLUSION

Assessment takes place all the time because making judgements is something that everyone does personally and to others. This study discussed the rationale behind the four assessment components, ie verbal progress report, formal project presentation, group written report and individual written report, as a means of assessing students studying BSE at the Hong Kong Polytechnic University. In particular, the weighting factors for the assessment components of DPB subjects in four academic programmes at the degree and sub-degree levels offered by the University and their relevance were examined, in order to correlate the students' overall performance and the DPB subject results by rank correlations. The significance of each assessment component was evaluated with the existing weighting factors for assessing students' work of DPB subjects. The results indicated that formal project presentations were associated with the highest correlation in all the sample groups, while verbal progress reports had the lowest.

The weighting factor is a contributory influence that ensures constructive learning experiences for students. Based on the findings and the developed protocol, it is recommended that very careful consideration be given to the weighting factors for a subject before launching.

This study found that the weighting factors of a subject could be determined by maximising the rank correlation between the DPB subject results and the overall academic performance of students. It also presented a template of procedures in determining the weighting factors of a subject that would be helpful in preparing a guideline for project-based assessment implementation.

Without quantifying the assessment criteria, the existing assessment components were polished with appropriate weighting factors from the newly developed protocol. This protocol would be helpful in developing a guideline for assessing students' work of DPB subjects for engineering education.

REFERENCES

1. Office for Standards in Education (OFSTED), *Good Assessment in Secondary Schools*. London: OFSTED (2003).
2. Louis, C., Lawrence, M. and Keith, M.A., *Guide to Teaching Practice* (5th edn). New York: Routledge Falmer (2004).
3. Department of Building Services Engineering (BSE), Programme documents, BEng(Hons) in Building Services Engineering, Higher Diploma in Building Services Engineering. Hong King: Department of BSE, Hong Kong Polytechnic University (2004).
4. Au Yeung, Y.N., Gow, L., Lai, C.C., Ho, W.F., Sivan, A. and Ledesma, J., Action research in industrial training in BSE course. *Inter. J. Educnl. Management*, 6, **4**, 26-29 (1992).
5. Chow, W.K., Wong, L.T., Chan, K.T., Fong, N.K. and Ho, P.L., Fire safety engineering: comparison of a new degree programme with the model curriculum. *Fire Safety J.*, 32, **1**, 1-15 (1999).
6. Ho, M.L., Rad, A.B. and Chan, P.T., Project-based learning. *IEEE Control Systems Magazine*, **4**, 88-91 (2004).
7. Siu, K.W.M., Reconstructing the learning environment for the new needs in engineering training. *Engng. Science and Educational J.*, 0, **3**, 120-124 (2001).
8. Hollander, M. and Wolfe, D.A., *Nonparametric Statistical Methods* (2nd edn). New York: Wiley (1999).
9. Kokoska, S. and Zwillinger, D., *Standard Probability and Statistics Tables and Formulae*. New York: Chapman and Hall/CRC (2000).

Table 1: Design project-based (DPB) subjects in four academic programmes.

Academic Programmes (Model of Study/Funding Sources/Award)	Stage of Study	DPB Assessment Results* (Grade Point)		
		Average	Highest	Lowest
(1) Full-time/government-funded/BEng(Hons), θ_1	(i) Final year; (ii) Non-final year	3; 3	4; 4	2.5; 2
(2) Part-time/self-funded/BEng(Hons), θ_2	(i) Final year; (ii) Non-final year	3; 3	4; 4	2; 2
(3) Full-time/self-funded/BEng(Hons), θ_3	(i) Final year; (ii) Non-final year	3; 3.5	4; 4	2; 2.5
(4) Full-time/government-funded/Higher diploma, θ_4	(i) Final year; (ii) Non-final year	3; na	4; na	2; na

*≥ 3.6 Excellent; 2.74-3.6 Very Good; 1.75-2.74 Satisfactory; < 1.75 Unsatisfactory; na = not applicable

Table 2: Rank correlation for DPB subjects.

θ_j	n_j	i	*a_i	Existing Weighting Factors			By Maximised r_s			By Maximised r_κ		
				w_i	r_s (P)	r_κ (P)	w_i	r_s (P)	r_κ (P)	w_i	r_s (P)	r_κ (P)
1	58	1	(a)	0.15	0.211 (0.1126)	0.155 (0.0850)	0.01	--	--	0.23	--	--
		2	(b)	0.20	0.389 (0.0025)	0.278 (0.0020)	0.37			0.27		
		3	(c)	0.40	0.370 (0.0043)	0.279 (0.0020)	0.25			0.35		
		4	(d)	0.25	0.387 (0.0027)	0.291 (0.0013)	0.37			0.15		
		Subject overall, $\Sigma a_i w_i$			0.509 (5×10^{-5})	0.363 (6×10^{-5})		0.536 (1×10^{-5})	0.385 (2×10^{-5})		0.527 (2×10^{-5})	0.387 (2×10^{-5})
2	98	1	(a)	0.10	0.347 (0.0005)	0.270 (8×10^{-5})	0.02	--	--	0.04	--	--
		2	(b)	0.30	0.557 (3×10^{-9})	0.403 (4×10^{-9})	0.34			0.32		
		3	(c)	0.60	0.534 (2×10^{-8})	0.390 (1×10^{-8})	0.64			0.64		
		4	(d)	0.00	--	--						
		Subject overall, $\Sigma a_i w_i$			0.617 (1×10^{-11})	0.455 (3×10^{-11})		0.623 (8×10^{-12})	0.448 (6×10^{-11})		0.622 (8×10^{-12})	0.451 (6×10^{-11})
3	110	1	(a)	0.10	0.420 (5×10^{-6})	0.317 (1×10^{-6})	0.17	--	--	0.17	--	--
		2	(b)	0.00	--	--	0.00			0.00		
		3	(c)	0.50	0.500 (3×10^{-8})	0.371 (9×10^{-9})	0.43			0.43		
		4	(d)	0.40	0.522 (5×10^{-9})	0.398 (7×10^{-10})	0.40			0.40		
		Subject overall, $\Sigma a_i w_i$			0.611 (1×10^{-12})	0.436 (1×10^{-11})		0.614 (1×10^{-12})	0.424 (5×10^{-11})		0.614 (1×10^{-12})	0.424 (5×10^{-11})
4	103	1 & 2	(a) & (b)	0.00	--	--	0.00	--	--	0.00	--	--
		3	(c)	0.79	0.268 (0.0062)	0.212 (0.0015)	0.35			0.39		
		4	(d)	0.21	0.339 (0.0005)	0.268 (6×10^{-5})	0.65			0.61		
		Subject overall, $\Sigma a_i w_i$			0.307 (0.0016)	0.224 (0.0008)		0.386 (6×10^{-5})	0.265 (7×10^{-5})		0.386 (7×10^{-5})	0.266 (7×10^{-5})

*(a) Verbal progress report; (b) Formal project presentation; (c) Group written report; (d) Individual written report; -- = not applicable