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An Academic Results Analysis of a First Year Interdisciplinary Project Approach to Industrial and Management Engineering Education

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Abstract

This paper presents an analysis of academic results of first year Industrial Management and Engineering students, achieved either in a PLE (Project-led Education) or in a non PLE teaching and learning approach. Data collected focuses on students' grades, including continuous and summative assessment results of four different courses, from the academic year 2006/2007 to 2008/2009. The evaluation indicators used are the ratio of students assessed and those enrolled in the course, the ratio of students approved and those enrolled in the course, the ratio of students approved and those assessed in the course, the arithmetic mean and the standard deviation of student grades. Findings suggest that PLE students, in average, have better results than the non PLE students at all courses and for the three academic years analyzed. However, these results need to be understood in a broader perspective which includes other variables such as student background, student engagement of given tasks, etc. which are beyond the scope of this paper.

Keywords: Academic results; Interdisciplinary Project; Engineering Education; Assessment.

1 Introduction

Strongly encouraged by the demands of the Bologna Process, interdisciplinary project approaches in engineering curricula have been adopted in a number of Higher Education Institutions (Heitmann, 2005; Helle, Tynjälä & Olkinuora, 2006). By learning through interdisciplinary projects and teamwork, students have the possibility to achieve a deep understanding of concepts, as they move from merely listening and reading about abstract concepts, to working with their teammates in applying those concepts to solve large-scale open-ended projects (Powell & Weenk, 2003). Project approaches also enhance student motivation and respond to the drop out problems and underachievement faced by first year students in Engineering programs (Tavares, Santiago & Lencastre, 1998; Tavares & Santiago, 2001).

In these kinds of approaches to teaching and learning, assessment of student learning has been subject to several discussions. Different concerns emerge when designing student centred assessment methods, as the emphasis is not only on the assessment of the outcomes but also on the process of learning. As the literature on the implementation of project and teamwork in engineering curricula shows, this approach to learning intends not only to deepen students' learning in regard to the technical competencies required for an Engineering profession, but also to improve students' ability to work and cooperate with others, as this is an important issue which is not enhanced or either assessed in traditional learning environments. Nowadays, engineers are, indeed, expected to demonstrate skills related to problem solving, project management, leadership and decision making, amongst others. Project approaches to teaching and learning strongly encourage the development and assessment of these transversal competencies (Becker, 2006; van Hattum-Janssen & Vasconcelos, 2007).

Formative assessment plays an important role in the learning process as it provides students with feedback about their performance, allowing them to improve their work. However, the effects of formative and summative assessment in learning, from students' point of view, are relatively different (Boud, 2000). It seems that the influence of formative assessment is subtler than summative assessment and that the latter seems to drive out learning at the same time it seeks to measure it. Students usually see assessment as the most important result of their learning process. No matter how or when it takes place, it is always the centre of their learning efforts (Boud 2000; Lindberg-Sand & Olsson, 2008).

Assessment practices that enable students to grow and develop tend not to fit in with the kinds of tests and examinations that are set, mostly due to university guidelines and professional requirements (Savin-Baden, 2004). Therefore, different attitudes towards assessment may be found ranging from those who believe that assessment is about measuring competence and improvement through tests that are seen to be reliable and valid, to those who see assessment as a means of demonstrating effective learning in the curriculum, and to those who see it as a means of ensuring that students have learned (Savin-Baden, 2004).

Students' academic achievement is an important indicator of the quality of a given program or project. This is particularly relevant when implementing new approaches to teaching and learning, in so far as both teachers and students are quite concerned with assessment results. Previous empirical studies, based on qualitative and quantitative data collected in the context of problem and project based learning experiences, stress the importance of understanding the impact of assessment on students (Sambell, *et al.*, 1997; Verhoeven *et al.*, 1998; Polanco, Calderón & Delgado, 2004; Savin-Baden, 2004; Struyven *et al.,* 2005). For instance, Verhoeven *et al.* (1998) compared the academic achievement of students by applying a Progress Test to students from two Dutch medical schools, one employing Problem-Based Learning (PBL) and one with non-PBL methods. Findings suggest that there were no systematic differences found in the two administrations of the Progress Test. The test scores indicated that the effects of PBL and non PBL instructional methods on medical factual knowledge were very similar. However, when analysing test scores split into three categories (basic, clinical and social sciences), the results show that the basic sciences favoured the non-PBL curriculum and the social sciences the PBL curriculum. Besides this, an interesting conclusion of this study was that medical students, at the end of their curricula, master the same kind of knowledge, it is only the moment in time that they learn it that differs.

Also, at the University of Minho, a qualitative study based on students' perceptions about assessment in Project-Led Education (PLE) stressed that students were rather concerned with PLE's grading system and often compared grades achieved in PLE with those achieved in other semesters, with non PLE approaches (Fernandes, Flores & Lima 2009a). Students argue that, at the end of the semester, they get a relatively low return in terms of marks, feeling unrewarded in regard to the heavy workload and study effort which the project-led education entails. For this reason, some students stated that they prefer traditional lectures and assessment procedures, as they are not dependent on a group component and the effort required to achieve the intended learning outcomes is much less. In this way, assessment is perceived as fairer and more appropriate in non PLE approaches, as it allows students to achieve higher grades which are exclusively focused on individual performance. By studying harder, some students claim to master the courses' main topics and to be successful in sitting exams.

The main goals of this paper are to analyse grades of students in PLE and non PLE teaching and learning approaches, and to discuss the main findings arising from the data analysis. For this purpose, comparable assessment elements will be used which, in this case refer to the final specific content assessment results from involved courses. In other words, for PLE students, academic final results for each course before adding the interdisciplinary project grade component will be used. In order to analyse the major differences in academic results between project and non-project students, it is important to understand that student's profile and background have influence on the learning success and students' outcomes in each of the learning approaches. Being a working student or being repeating a course are some aspects that could influence students' results, learning tasks, assessment methods, etc. However, these aspects will not be considered in this paper.

2 Case Study Context

In recent years, freshman students in Industrial Management and Engineering program (IME) at the University of Minho have participated in Project-Led Education (PLE), during the first semester of their Masters degree course (Lima *et al.*, 2007). Every year approximately 40 students have enrolled in PLE, forming teams of 6 to 7 students.

The first semester of the first year of IME includes five courses: Introduction to Industrial and Management Engineering (IEGI), Computer Programming (PC1), Calculus (CC), General Chemistry (QG) and Introduction to Economic Engineering (IEE). According to Powell & Weenk (2003), all courses integrated in a Project-Led Education experience are project supporting courses (PSC). In this Masters degree there is no course dedicated to the project content. So, the interdisciplinary project acts like an interconnection pedagogical mechanism amongst all PSC courses. All the courses of the first semester, except IEE, are project supporting courses (PSC). Most of the teachers involved in these courses have been the same over the last few years, being Calculus the only exception. Since the first semester of IME is based on an innovative project approach, the stability of teaching faculty has helped faculty staff involved in this approach to apprehend the methodology concept and to develop pedagogical materials and strategies, as changes in course contents and learning outcomes must be (re)adapted in order to meet the projects' goals and students' needs. The teaching faculty allocated to this programme is represented in Table 1. The larger variation can be identified in CC, where a new teacher (T6, T7 and T8) is chosen every year, by the Math Department, to teach this course. This is the course in which higher difficulties of content integration have been identified both by students and teachers (Fernandes, Flores & Lima, 2009b).

Table 1: Teaching faculty in the first semester of the first year of IME (from 2006/2007 to 2008/2009)

Years	IEGI	QG	PC1	CC	IEE
2006/07	T1+T2	T4	T5	T6	T9+T10
2007/08	T1+T2+T3	T4	T5	T7	T9+T10
2008/09	T1+T2+T3	T4	T5	T8	T9+T10

In this project approach to teaching and learning, assessment is mainly formative based on continuous assessment and feedback both on PSC and project components (Carvalho & Lima, 2006). This paper focuses upon an analysis of students' grades, so a description of the grading model is necessary to contextualize the results. Students receive grades for each PSC course and these are based on PSC specific content assessment and project interdisciplinary assessment. Each PSC defines its own way of assessment based on different activities that can include small group tasks, work assignments and/or written tests. The project interdisciplinary grading is mainly based on the final project product with a 40% impact on PSC final grade. The final project product includes a group grade based on a final report (35%), its revision after feedback from teachers (25%), developed prototypes (20%) and a final public presentation and discussion (20%). This group grade has an individual correction factor that depends on intra-group peer assessment. This grade has an 80% weight and a written test on the group project has a 20% weight on final individual project grade. All courses have a complementary optional assessment opportunity for students to pass, which can be, for instance, a written test. Most of the impact on PSC specific content final grade in each course is related, as mentioned above, with continuous assessment activities. This is true both for PLE and non PLE students' assessment that is based mainly on individual performance, by completing the same courses' assignments. This is a component of assessment mostly equivalent between PLE and non PLE students. So, course's specific content assessment grades will be the core element of analysis.

3 Academic Results Analysis

In this paper, the academic results of first year students, achieved either in an interdisciplinary project approach or in a non PLE teaching and learning approach, in Industrial Management and Engineering will be analyzed. Data collected focuses on students' grades, including continuous and summative assessment results, throughout three academic years (2006/2007 to 2008/2009). In this analysis, two groups of students are included – those who participate in PLE, where the assessment method itself contributes to the students final classification in the different courses involved, and those students who do not participate in the PLE process (NPLE students). The number of students in each group (PLE and non PLE) varies from course to course and is also different in each academic year (see Table 3).

Table 2: Number of Students in PLE and NPLE groups

Years	*Number of*	*IEGI*		*QG*		*PC1*		*CC*		*ALL COURSES*	
	Students	*PLE*	*NPLE*	*PLE*	*NPLE*	*PLE*	*NPLE*	*PLE*	*NPLE*	*PLE*	*NPLE*
2006/07	*Enrolled*	39	14	39	15	39	18	38	61	155	108
	Assessed	39	10	39	4	39	4	38	25	155	43
	Approved	38	4	36	2	30	2	21	10	125	18
2007/08	*Enrolled*	41	23	41	35	41	50	41	42	164	150
	Assessed	41	23	39	12	41	11	40	40	161	86
	Approved	40	18	39	4	38	9	27	10	144	41
2008/09	*Enrolled*	38	27	38	32	37	35	38	72	151	166
	Assessed	38	14	38	18	37	13	36	46	149	91
	Approved	38	12	37	14	31	9	25	7	131	42
ALL YEARS	*Enrolled*	118	64	118	82	117	103	117	175	470	424
	Assessed	118	47	116	34	117	28	114	111	465	220
	Approved	116	34	112	20	99	20	73	27	400	101

The evaluation indicators used are the ratio of students assessed to those enrolled in the course, the ratio of students approved to those enrolled in the course, the ratio of students approved to those assessed in the course, the arithmetic mean and the standard deviation of student grades. Table 3 represents a set of evaluation indicators that were selected for this study. Max indicator represents the higher grade of each set of students. Min indicator represents the lower grade of each set of students. A student is considered approved with a grade higher or equal to 9.5 out of 20. The Average and Standard deviation are other two indicators computed in each set of students. Three others indicators are the ratios between approved and assessed, approved and enrolled, assessed and enrolled students in each set.

Table 3 shows that in almost all cases the set of PLE students have better results than the other set of students. The only exception was identified in PC1 course with a similar average for both set of students. When Max indicator was compared for PLE and NPLE students, PLE students achieved higher grades than NPLE students, although in some courses the difference was more significant than others. When Min indicator was compared for PLE and NPLE students, PLE students achieved approximately equal grades than NPLE students, as expected because the sample included only the approved students. All these values were obtained using the Approved students, so the sample dimension varies from course to course each year (see Table 3).

Table 3: Grade analysis for the three academic years (2006/2007 to 2008/2009)

2006/07	*IEGI*		*QG*		*PC1*		*CC*	
Indicators	*PLE*	*NPLE*	*PLE*	*NPLE*	*PLE*	*NPLE*	*PLE*	*NPLE*
MAX [9.5, 20]	18.4	16.6	17.2	12.7	14.8	12.7	19.0	14.0
MIN [9.5, 20]	9.5	9.7	9.5	11.2	9.5	9.5	9.5	10.0
Average	15.0	11.7	11.9	11.9	10.9	11.1	12.6	11.4
STD	2.2	3.3	1.9	1.1	1.6	2.2	3.1	1.3
Ratio assessed/enrolled	100.0%	71.4%	100.0%	26.7%	100.0%	22.2%	100.0%	41.0%
Ratio approved/enrolled	97.4%	28.6%	92.3%	13.3%	76.9%	11.1%	55.3%	16.4%
Ratio approved/assessed	97.4%	40.0%	92.3%	50.0%	76.9%	50.0%	55.3%	40.0%
2007/08								
Indicators								
MAX [9.5, 20]	17.3	17.4	16.2	14.6	14.0	12.9	16.8	12.3
MIN [9.5, 20]	12.2	10.9	9.5	9.5	9.5	9.5	9.5	9.6
Average	15.4	14.3	12.0	12.2	10.8	11.0	12.1	10.6
STD	1.3	2.0	1.7	2.2	1.2	1.3	2.1	0.9
Ratio assessed/enrolled	100.0%	100.0%	95.1%	34.3%	100.0%	22.0%	97.6%	95.2%
Ratio approved/enrolled	97.6%	78.3%	95.1%	11.4%	92.7%	18.0%	65.9%	23.8%
Ratio approved/assessed	97.6%	78.3%	100.0%	33.3%	92.7%	81.8%	67.5%	25.0%
2008/09								
Indicators								
MAX [9.5, 20]	17.4	17.3	18.9	17.5	15.6	13.8	18.4	12.0
MIN [9.5, 20]	10.0	11.4	9.5	9.5	9.5	9.6	9.5	9.5
Average	14.6	14.1	14.0	12.2	11.6	11.5	13.4	10.5
STD	1.8	1.9	2.8	2.6	1.6	1.6	2.6	0.9
Ratio assessed/enrolled	100.0%	51.9%	100.0%	56.3%	100.0%	37.1%	94.7%	63.9%
Ratio approved/enrolled	100.0%	44.4%	97.4%	43.8%	83.8%	25.7%	65.8%	9.7%
Ratio approved/assessed	100.0%	85.7%	97.4%	77.8%	83.8%	69.2%	69.4%	15.2%

The ratios presented in the Table 3 show results that are more favourable for PLE students than for NPLE students, in all courses, and for the three academic years. In particular the ratio assessed/enrolled presents values above 94.7% for PLE students, whereas for NPLE students all values are below 63.4%, except one (IEGI 2007/08). Similarly the ratio approved/assessed is above 67.5% for PLE students, except one (CC 2006/07 with 55.3%), being above 90% in 7 out of 12 cases. For NPLE students, this ratio is placed between 15.2% and 85.7%. For the ratio approved/enrolled it can be verified that values are above 65.8% for PLE students, except one (CC 2006/07 with 55.3%), being above 90% in 7 out of 12 cases. For NPLE students, all values for this ratio are below 44.4% except for IEGI 2007/08 with 78.3%. The dimension of the sample for the ratio assessed/enrolled and approved/enrolled is the number of enrolled students on each course and each year. The dimension of the sample for the ratio approved/assessed is the number of assessed students on each course and each year.

Figure 1 represents averages of students' grades for each course in the three academic years. For PLE students these averages are predominantly above the average of NPLE students. However, there are 4 cases out of 12 where this is not true: QG 2006/07 with equal averages; QG 2007/08, PC1 2006/07 and 2007/08 with two decimal places of difference.

Figure 1: Average of students' grades for each course in the three academic years

Analyses were performed using Statistical Package for the Social Sciences (SPSS, version 17.0). To analyse the academic results of PLE and NPLE group of approved students in all years, a boxplot graphic was prepared (Figure 2), based on total number of approved students on all courses (PLE – 400; NPLE - 101). The middle line of the box indicates the median of the academic results for each of the two groups of students, PLE and NPLE (≈12.7 and 11.8, respectively). The highest and the lowest results are also presented (limits of the vertical lines). It can be observed that, though the minimum values practically coincide for both cases (9.5), the maximum occurs for the PLE students (19.0). The NPLE group of students presents lower amplitude, i.e. variability in academic results. It also can be observed that 75% of the of PLE students gets grades approximately lower than 15.0, and 13.6 for the NPLE students.

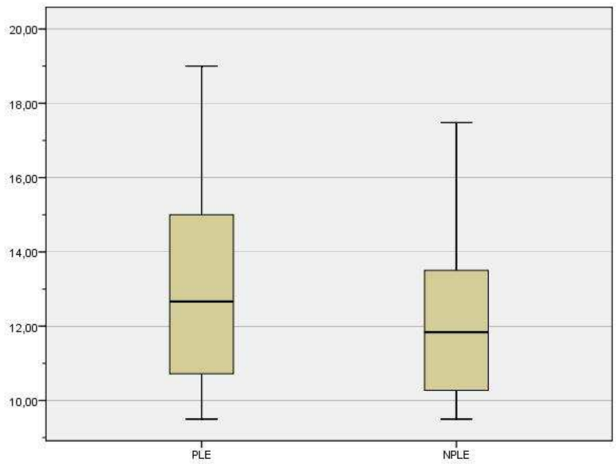

Figure 2: Distribution of grades for the PLE and NPLE students.

Kolmogorov-Smirnov test compare two distributions of values whereas the null hypothesis, for the present analysis, is that PLE and NPLE academic results are from the same continuous distribution. The alternative hypothesis is that they are from different continuous distributions. Analyses for each of the four courses (IEGI, QG, PC1 and CC) were performed, being the dimension of the sample equal to the number of approved students in all years for each course (see Table 2). Table 4 summarizes the Sigma values obtained for this study analysis. A Sigma (p) value less than 0.05 means that the two groups of students have different behaviours. For both groups, the distribution of IEGI and CC students' academic results were significantly different ($Z = 1.781$, $p = 0.004$ and $Z = 1.826$, $p = 0.003$, respectively). These results confirm the analysis previously made by using the average students' results, as presented in Figure 1, and that, for these courses, the averages of PLE students are higher than NPLE students.

Table 4: Statistical measurements values obtained in the Kolmogorov-Smirnov tests

PLE/NPLE	IEGI	QG	PC1	CC
Z	1.781	0.777	0.948	1.826
Sigma (p)	0.004*	0.582	0.330	0.003*

* Statistical significant at the 0.05 level.

4 Conclusion

We are aware that a large number of variables influence students' grades and that the teaching and learning strategy adopted is not the only variable to take into account when analysing students' academic success. However, as stated earlier in this paper, assessment is an important concern for both students and faculty staff, especially when innovative methods and procedures are adopted, in which student grading is sometimes questioned.

In regard to the statistical analysis carried out, some differences were found between PLE and non PLE students' academic results. PLE students, in average, achieved better results than the non PLE students at all courses and for the three academic years analysed. This is particularly relevant in the case of courses with a tradition of low approval rates, as Calculus C, for instance, where a higher number of students were approved due to the project methodology. Besides this, data analysis point out that 25% of PLE students achieved grades higher than 15.0, whereas, for non PLE, this value reduces to 13.6. However, although students' grades are mainly higher for PLE students than for non PLE students, the median values were quite similar (≈12.7 and 11.8, respectively). Therefore, there is not a big difference in terms of results.

This is an interesting finding as qualitative data collected from students, on a previous study, had suggested a different perspective (Fernandes, Flores & Lima, 2009a). PLE students argued, during focus group discussions and on answers to open-ended surveys, that one of the main disadvantages of PLE methodology was that students' final grades in this approach to teaching and learning were lower than in non PLE approaches This, however, was based exclusively on students´ own perceptions in regard to the assessment method and the results achieved in PLE. Students who participated in PLE experiences also recognised the importance of a set of other non technical competencies which were enhanced throughout the projects' development, such as the ability to work in teams, to manage time, to take responsibility, to solve problems and to handle motivation. Although this paper focuses mainly on the analysis of academic results in PLE and non PLE students, these outcomes cannot be put aside as they represent the added value of implementing interdisciplinary project approaches within first year Engineering students. Also, it would be interesting to do a more comprehensive study focusing not only on students' academic results but also on other variables that might help explain both similarities and differences in the two groups.

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