CORRELATION STUDY BETWEEN THE ACCESS MARK AND THE PERFORMANCE IN PROJECT-BASED AND STANDARD COURSES

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Conference Key Areas: *Entrepreneurship Education, Engineering Skills*
Keywords: *Capstone Project, Access grades, Project-based learning*

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doi:10.5821/conference-9788412322262.1168

ABSTRACT

The access mark to engineering studies is often used as an a priori success estimator. In our institution, we have observed that the correlation of the access mark with the grades obtained in project-based courses (R=0.52) is slightly lower than the one obtained with the average of the other non-project-based courses (R=0.58), and is especially low in capstone projects (R=0.31). Project-based and Challenge-based courses are one of the most acknowledged ways of promoting the learning of transversal skills, specifically innovation and entrepreneurship skills. In our institution, ICT engineering bachelor students perform a project-courses path, with three subjects of growing complexity in the 2nd, 3d and 4th year. While the first two are partially guided and with challenges proposed by the faculty members, the 3d one is a 12 ECTS capstone project with challenges proposed by industry or external institutions. In this study, we have analyzed the performance of the students along 10 academic years (2011-2012 to 2020-2021). Not only the correlation with the access mark in these courses is lower but the prediction interval is also different. While it is almost impossible that a student with a low access mark gets an outstanding average mark in the bachelor and vice-versa, there are students with a low access mark which have an outstanding performance in the capstone project and students with a very high access mark and with high results in analytical courses but with a poor performance in capstone projects. Therefore, a different kind of skills are promoted in these courses.

1 INTRODUCTION

1.1 Project-Based courses

Nowadays it is widely acknowledged that what is expected from future engineering graduates is far more than technical skills or disciplinary engineering knowledge. Initiatives and institutions like ABET, CDIO, NAE or ENAEE–EUR-ACE have stablished lists of personal, interpersonal and professional competences. This need of competences' development has been widely addressed from the academia in several ways. Project-Based Learning and, specifically, Capstone design courses where student teams develop "real" projects using their theoretical knowledge on a system level [1], [2] are considered among the more successful tools to promote that kind of skills.

The Bachelor in Telecommunication Technologies and Services Engineering at the School of Telecommunications Engineering of Technical University of Catalonia, in Barcelona, includes three project-based courses in order to provide a framework to facilitate the learning of personal, interpersonal and professional skills. The CDIO model [3] was used in the design of the program, which was completed 10 years ago. The three project-based courses are "Introduction to Engineering" (2nd year, 6 ECTS), "Basic Engineering Project" (3rd year, 6 ECTS) and "Advanced Engineering Project" (AEP, 4th year, 12 ECTS). In the first two subjects, students work in small teams (3-5 students) following a partially guided plan which also includes some disciplinary contents learning and in which the project topic is proposed by the supervisors. Although the goal of the three courses is to provide a context close to the practice of engineering, the first two are closer to PBL methodology [4], providing

both context and contents through a known and guided sequence of activities. On the other hand, AEP, the third one, follows the Product Development Project (PDP) model, which can also be assimilated to the New Product Development model [5]. In this course, bigger working groups (8-12 students) carry out the design of a complete product or service, including its business model. The teams generate the requirements and specifications of the product or service from the initial interaction with the stakeholders, define the system block structure and the work packages and then distribute them among subgroups of 2-3 students. They must design, implement and test the subsystems, integrate them, define a business model based on the product or service and perform the sustainability and ethical analysis. In the first years (2011-2014) the challenges of the AEP projects were proposed by the teaching staff. Since then, external agents were gradually incorporated and currently, 7 out of 10 challenges are proposed by companies, hospitals, foundations or NGOs. This subject is compulsory and 1440 students have passed through it. They have worked in 138 different projects, being 81 of them proposed by external agents. Some examples of project challenges are: image processing software for rehabilitation of facial paralysis due to facial nerve injury, human-machine interface techniques for car cockpit, development of sensors for 3D printers, blockchain-based payment distribution system in the music industry or low-cost IoT sensor system for detection of irregular discharges in wastewater. A comparative study of the performance of the student teams according to the kind of stakeholders (internal/external) and other features of the projects has been reported in [6]. The AEP course is performed twice per academic year. There are around 10 different projects in the Fall term and around 7 in the Spring term. In the Fall term, 10-15 students perform AEP in a different way, following a Challenge-Based Learning (CBL) model [7] in multidisciplinary teams. A quantitative and a qualitative study on the differences in the learning of innovation skills among PDP and CBL modalities have been reported in [8] and [9] respectively. The learning outcomes of the course are mostly the ones of the involved personal, interpersonal and professional generic skills. Of course, there are learning outcomes associated to the disciplinary topics involved in the project development but they are considered as a reinforcement of the previous or parallel disciplinary subjects.

1.2 The effect of previous academic achievement

Previous academic achievement is usually considered a good a priori estimator of academic success in higher education. Most studies, for example, [10] are centered in the success in the first-year attainment and in the drop-out rate. Putwain et al [11] studied its effects in academic self-efficacy. The literature about its effect on the project-based courses is less abundant. Garry [12] concludes that student groups with high GPAs, on average, do well on their capstone projects after studying several success factors. Joo et al [13] state that PBL benefitted low performing students to a greater extent and decreased the achievement gap, but applied to secondary education.

The secondary education system in our country defines a University access exam when the students finalize their High School years. This exam includes several disciplines, some of them are common to all student and some others are specific for

the kind of bachelor the students are going to enroll (scientific/humanities). The resulting mark is averaged with the mark of the last two years of the secondary education and provides a grade in a scale of 10 points. This grade can be improved by performing two additional exams on subjects specifically indicated for the kind of bachelor the students are going to enroll (usually Advanced Mathematics, Physics, Chemistry or Technology for Engineering studies), which can provide up to 4 additional points. Then, the University Access Mark is defined on a scale of 14 points. It is used as a ranking criterium to determine the access to each bachelor in each institution when there is more demand than available positions.

The initial hypothesis of this study is that the regular courses (the non-project-based courses) marks will be correlated with the access mark of the students and that the project-based courses mark, and specifically the AEP mark, will not be so correlated because a set of different skills, non-so analytical, are developed in these courses.

2 METHODOLOGY

Out of the 1440 students that have carried out the AEP capstone course between the academic years 2011-2012 and 2020-2021, we have included in the study the 1257 that had finished the bachelor when doing the analysis, so they had completed all the courses of the program. Their access marks are included in the range 5.00 – 13.78 (in a 14 points scale), with an average mark of 9.97 and a standard deviation of 1.93 (7.12 and 1.38 in an equivalent scale from 0 to 10). Half of the students are included in the range 8.70 – 11.50, while 25% joined our school with more than 11.50 points (8.21/10) and 25% with less than 8.70 (6.21/10). The students that enter our engineering degrees with an access mark lower than 8/14 have a high drop-out rate. Only the ones that reached the AEP course and finished the bachelor have been included in this study.

To check the validity of the hypothesis, we have performed a correlation study between the access mark and several performance indicators, most of them derived from the AEP subject individual mark. Assuming the limitations of the individual final grade as a valid metric to assess the performance in the course, we have chosen it as performance index for this study because of its integrative character. According to the learning outcomes of the course, the project supervisors assign a team mark, which reflects the assessment of the process (50%) (Preliminary and Critical Design Review, team dynamics) and the final result (50%) (Solution Technical Performance, Business Idea, Final Report, Final Presentation and Video). The individual marks are obtained from this team mark after applying a triple modulation (30% max): The Supervisors' Assessment of the individual performance, the Team Leader assessment (batch of points) and the Peer Assessment using a 10 criteria rubric. Therefore, the final individual marks are quite integrative of several aspects. The average of the individual marks along the 10 years of the study is 8.44 in a scale of 10, with a standard deviation of 1.17.

The parameters included in the correlation study are:

- The average of the grades of the regular courses (non-project courses), most of them with a high analytical content.

- The average of the grades of the two first project-based courses (PBL courses mark).
- The individual grade of the AEP course.
- The relative increment or decrement of the individual AEP mark respect of the team mark (individual boost).
- The individual grade of the AEP course separating the cases in which the project main stakeholder was internal or an external company or institution.

For each of them, the Pearson's R correlation coefficient was obtained and the linear regression between each indicator and the access mark was represented, including the +/- 95% prediction interval around the regression line. The analysis tool we used was SigmaPlot 14.5 (Systat Software, UK).

3 RESULTS AND DISCUSSION

3.1 Results

The results of the correlation analysis are displayed in the following graphs and tables. Table 1 displays the mean and standard deviation for each indicator and also the Pearson's R coefficient for the correlation between each indicator and the access mark.

Table 1. Mean and STD of each indicator and Pearson's R coefficient for the correlation between each indicator and the access mark.

Indicator	Mean	STD	R
Non-Project mark	6.75	0.69	0.58
PBL courses mark	7.25	0.88	0.52
AEP mark	8.44	1.17	0.31
AEP % individual boost	0.7%	13.0%	0.21

Figures 1 to 4 display the linear regression between each indicator and the access mark. The thick red lines display the linear regression line and the 95% confidence interval of the regression while the dashed red lines indicate the +/- 95% prediction interval of the indicator if the regression is used for this purpose. All graphs have the same axes scale in order of making easier their comparison.

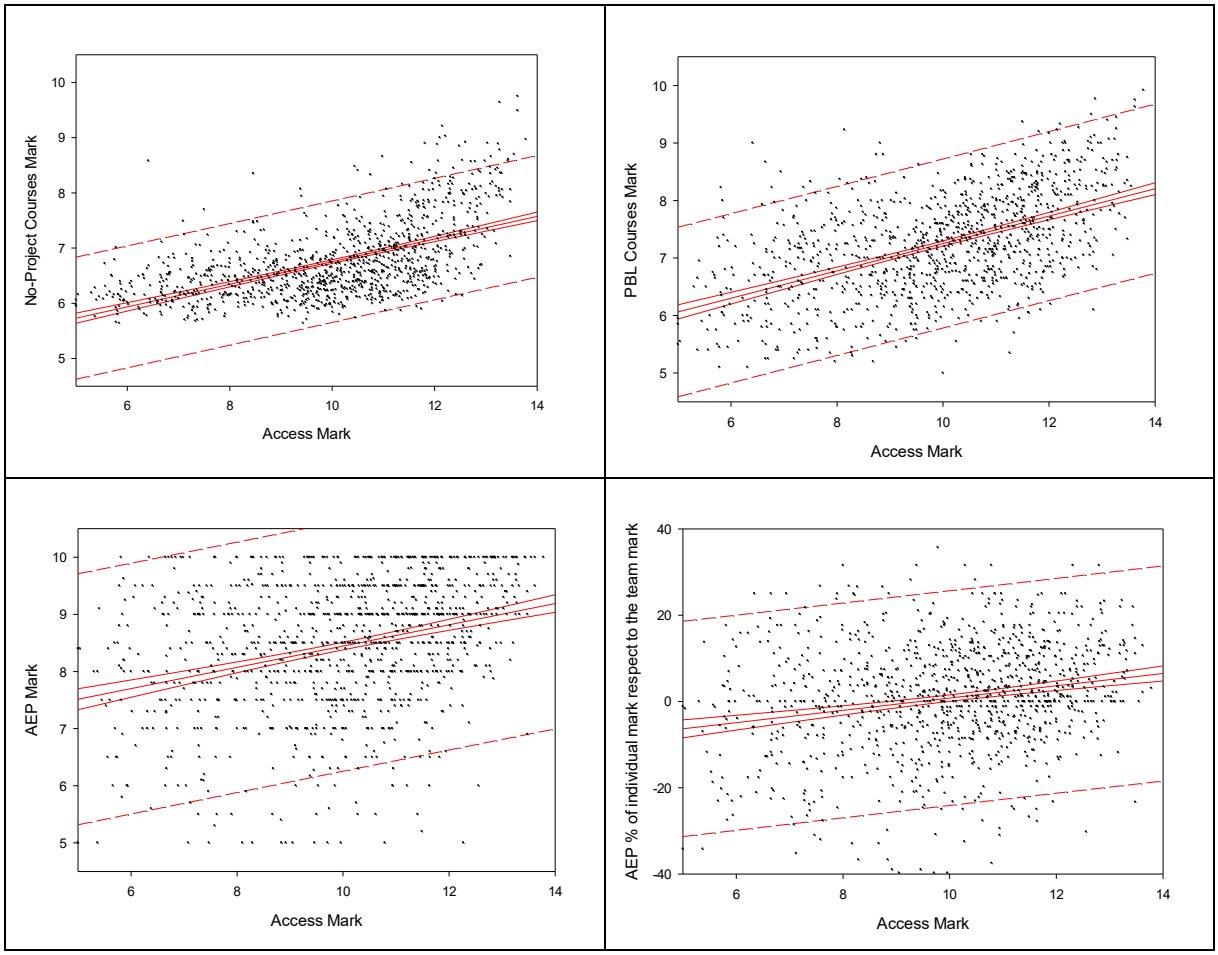

Fig. 1. Correlation Access Mark – Non-Project Courses Mark (top, left); Correlation Access Mark – PBL Courses Mark (top, right); Correlation Access Mark – AEP capstone course individual Mark (down, left) and Correlation Access Mark – relative increment or decrement of the individual AEP mark respect of the team mark (down, right).

In order to compare the likelihood of obtaining a good indicator having had a low access mark or a bad indicator having had a high access mark, the regression value (RV-6) and the upper 95% prediction value (UPV-6) for an access mark of 6 and the regression value (RV-13) and the lower 95% prediction value for an access mark of 13 (LPV-13) are provided in Table 2.

Table 2.Regression and prediction limit values for an access mark of 6 and 13

Indicator	RV-6	RV-13	% RV	UPV-6	%Improv	LPV-13	%Improv
Non-Project mark	5.94	7.37	21%	7.06	19%	6.25	-15%
PBL courses mark	6.30	7.97	23%	7.75	23%	6.52	-18%
AEP mark	7.70	9.00	15%	9.90	29%	6.80	-24%
AEP % individual boost	-4.9%	5.1%	10%	20.1%	25%	-19.9%	-25%

The individual grade of the AEP course separating the cases in which the project main stakeholder was internal or an external company or institution has not delivered

significative differences among them, providing a Pearson's correlation coefficient of 0.30 for the first case and of 0.29 for the second one, very close to the global AEP one and a low correlation in any case.

3.2 Discussion

As we can see in Table 1, all the Pearson's R correlation coefficient are positive, displaying some better performance for the students with a higher access mark but is not high in any of the cases. The 0.58 value obtained with the correlation study between the Access Mark and the Non-Project Courses Mark can be considered as moderate [14], although we can observe in the corresponding linear regression graph in Figure 1 a clear dependency among both variables and a tight confidence interval for the regression. The correlation for the average of the two partially guided PBL courses is slightly small (R=0.52) but still moderate. The relevant difference can be observed with the AEP course, for which the correlation is weak (R=0.31). Looking at the corresponding graphs in Figure 1, we can see that, while it is almost impossible that a student with a low access mark gets an outstanding average grade in the bachelor and vice-versa, there are students with a low access mark which have an outstanding performance in the capstone project and students with a very high access mark and with high results in analytical courses but with a poor performance in capstone projects. This feature has been systematically observed by the project supervisors and commented in the coordination meetings, but we did not have a quantitative evidence. To avoid the possible bias eventually induced by the fact that the students with low access mark were assigned to projects that obtained higher marks (which is not reasonable), we also calculated the "Individual Boost" of each student, the relative increment or decrement (%) of the individual AEP mark respect of the team mark. A student with a high and positive Individual Boost has been acknowledged by his or her colleagues, by the Team Leader and by the supervisors as a valuable contributor to the success of the Team. The correlation between the Access Mark and the Individual Boost gives the very weak correlation of R=0.21, displaying that almost any student, independently of his or her access mark can receive a good or bad assessment by the peers. We have not done a study of a parallel assessment of the skills associated with the Team Work related skills such as commitment or leadership, which may be independent of the analytical skills, but they are probably playing a relevant role in this result.

In order to obtain quantitative indicators of the likelihood of obtaining a good indicator having had a low access mark or a bad indicator having had a high access mark, we have taken two extreme cases of access mark, 6 and 13 (in the scale of 14 points), which only have a 3% of the cases below and above respectively and have compared the estimated average indicator value through the regression line (RV-6) and the upper 95% prediction value (UPV-6) for the access mark of 6, to display the ability of obtaining a high indicator with a low access mark. Also the estimated average indicator value through the regression line (RV-13) and the lower 95% prediction value for an access mark of 13 (LPV-13) to display the ability of obtaining a low indicator value with a very high access mark. The results can be seen in Table

2. The 4th column, %RV, expresses the relative advantage of a student with an access mark of 13 respect to the one with an access mark of 6, calculated as the percentual change respect to the overall average of the indicator. We can see how, for the non-project courses, this advantage is 21% and similar for the PBL courses, but is reduced to 15% for the AEP capstone course and to 10% for the Individual Boost. In columns 5 (UPV-6) and 6 (% improvement) we can see how big is the maximum expectable value (95% confidence) for a student with a low access mark, respect to its average indicator value according to the regression. While a maximum of 19% can be expected for the non-project courses, up to a 29% can be expected for the AEP course and a 25% for the Individual Boost. On the opposite side, a student with a very high access mark can only expect a global result of -15% of decrement respect to his or her average mark in non-project courses according to the regression but up to a -25% in the AEP mark and the Individual Boost.

Further and specific research on direct measurement of the personal, interpersonal and professional skills involved in the performance in PDP projects would be needed to be able to determine up to which extent they are independent of the analytical skills, more relevant in the non-project based courses, but we consider that it is clear that a different kind of skills are promoted in these courses. We also consider that it is very positive that students that are not brilliant in most of the analytical courses could find a place to stand out. It enhances their self-confidence.

In any case, both the correlation coefficients, although weak, and the slopes of the regressions are positive and statistically significative ($p<0.001$ in all cases), which indicates a slightly better performance of the students with high access mark in the capstone AEP course, but what we consider relevant as result of this study is the evidence that students with low access mark are able of performing really well in that kind of courses, which are key for the complete education of graduate engineers. We recommend the institutions that perform or plan to perform that kind of courses to identify and highlight the good performance in capstone projects in students with average or even low marks in order to boost their self-confidence and self-efficacy.

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