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Impact of Using Automatic E-Learning Correctors on Teaching Business Subjects to Engineers*

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An innovative higher education is the visible outcome of the combination of the proliferation of Information and Communication Technologies (ICT) and novel approaches in education. We position our paper in this context, describing the experience of using an automatic e-learning corrector and its impact on both *academic results* and aspects of *student perception*. A total of 333 students doing technical degrees took a basic business administration course and the field work was conducted within this framework. An e-learning platform called *ACME_Business*, which automatically corrected and assessed all the exercises proposed, was designed, developed and implemented as the novel element of the course. The validity of the proposal was tested at the Polytechnic School of the University of Girona in Catalonia (Spain). The results show that implementing the solution is helpful in the learning process and in monitoring courses and that its use improves academic results. The perception assessment showed that the students had a very good opinion of the learning experience using the proposed ICT tool. Beyond these highlighted benefits for students, teachers save time and effort, and their workload is reduced. The novelty of the solution lies in the enormous potential for personalisation, the full automatization of exercise *generation, correction, feedback and grading*, and the dual educational approach wherein students gain knowledge in business administration and mastery in spreadsheet use.

Keywords: e-learning; business; engineering; Higher education; ACME

1. Introduction

Understanding the fundamentals of business administration should be a must in all Higher Education Institution (HEI) degrees, without exception. Engineering education has progressively promoted business knowledge and skills integration to complement a predominantly technical degree [1]. Graduate engineers as future professionals are encouraged to be able to demonstrate a sound, wide knowledge base and a deeper understanding of and competency in their speciality. However, regardless of their specialisation, they are implicitly expected to have business knowledge and skills [2, 3]. These aspects become mandatory given that students will be employed in business and as future employees they should understand how the organisations they opt to serve function [4, 5]. Global solutions designed, piloted, applied and evaluated by engineers in business settings essentially aim to enhance an organisation's competitiveness. Having a fair basic understanding of financial analysis, cost analysis, balance sheet and profit and loss account interpretation further contributes to making the most opportune decisions where both technical and non-technical details are important, forming a complex cohesion [6].

Despite the obvious need and the existing offer, the contradiction is that engineering students often struggle to understand the relevance of business content to their engineering training. Their motivation is usually lower (compared to specialty subjects) and the class configuration (early degree-stage subjects mean high numbers of students) places the educator in a challenging position where they must go beyond knowledge transmission and pay special attention to highlighting the usefulness of the subjects using examples from real-life settings and other motivational strategies and actions [7]. Teaching business administration content using **spreadsheets** is one of the strategies that best fits this reality, and as such is a solution that has gradually but intensively passed through the different stages from ideation to design, prototyping and piloting, implementation and continuous improvement [8].

Business administration is often taught to engineers using business administration-specific software tools. To counter engineering students' lower motivation for non-speciality subjects, we propose a spreadsheet-based interactive e-learning solution. Its proposed value consists in its dual approach: building on and further developing skills in spreadsheet use, while simultaneously training the funda-

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mentals of business administration. This approach adds novelty to early stage engineering education as it is more motivating than traditional methods using field-specific software solutions, connecting students to a problem-solution engineering philosophy, while allowing for field-specific problem statements fully adapted to the idiosyncratic issues of the different engineering fields (industrial firm, software development firm, etc.).

To this effect, the aim of this paper is to propose an innovative approach to teaching business to technical degree students, highlighting the use and impact of this solution, which is part of a global ACME framework (the acronym meaning *Continuous Evaluation and Educational Improvement* or Avaluació Continuada i Millora de l'Ensenyament, in the original language). More concretely, the paper explains how the *ACME_Business* solution was implemented in three business administration subjects taught as part of three different engineering degrees at the University of Girona (Catalonia, Spain) during the academic years 2015/2016 and 2016/2017. It also describes the impact of the global e-learning experience in terms of subjective and objective perspectives based on the results obtained from a student perception evaluation survey and the analysis of the activities and grades. This objective is part of wider and more ambitious goals, namely improving the teaching/learning experience, developing autonomous learning, furthering the knowledge acquired in academia and providing students with the opportunity to master ICT skills and acquire competence in using spreadsheets. Ultimately, we aim to contribute to narrowing the gap between *employer-required* and *graduate-acquired* competences.

Our contribution is part of a long-term experience described in a series of publications gathered in a trilogy. In the first publication [9], the authors describe the teaching experience using automatic spreadsheet correctors, while the second paper [10] focuses on the characteristics of the system and its integration in the learning experience. The present paper is the third in the trilogy, describing the most relevant aspects of *ACME_Business* and its impact on academic performance and student perception.

The paper is **structured** as follows. Following on from this **introduction** (Section 1) there is the **literature review** (Section2) in which the importance of spreadsheets is underlined and the published papers on automatic spreadsheet correctors highlighted. The description of the **methodology** follows, covering the technical and teaching facets of our proposal (Section 3). The **results** are presented in Section 4, which is divided into two sub-sections, one referring to the academic results and the other to the students' perception of the experience. The conclusions are drawn in Section 5, constituting a series of contributions for both teaching staff and students.

2. Related work and background

Regarding the business administration subjects students should be taught in an engineering or technical degree, we concur with the previous works of [11, 12], who highlight the importance of financial analysis, cost analysis, balance sheets and profit and loss accounts. There are a multitude of unrelated initiatives on teaching these subjects, all of which have the shared aim of improving the knowledge and skills of future engineers. These teaching experiences generally state the importance of theoretical sessions, emphasising the use of case studies [13] to illustrate the practical/application facet of the concept taught. As a complement to this traditional approach, a new stream of recent publications has emerged from authors such as [14], who consider that ICT-tools, e-learning platforms and project-based learning are technologies and trends towards which engineering education should evolve. Accordingly, [15] propose a learning system based on project design and development, while different authors such as [16] and [17] agree on the importance of combining face-to-face classes with activities requiring e-learning solutions, thus supporting the blended learning approach and practice. Among other factors, the authors [17] demonstrate the success of using 2.0 web tools as facilitators in a collaborative learning process. Some authors such as [12, 18, 19] highlight interactive on-line learning systems, unanimously agreeing on the importance of business administration training to an engineer's education to provide them with a good understanding of the firm—their current or future employment unit—from an economic perspective.

Complementarily, the use of specific software and e-learning platforms is emphasised in relation to innovation in teaching and learning, especially in specific circumstances such as where non-technical subjects are imparted to technical degree students. There are numerous initiatives using specific software, among which is [18], who developed an online system for learning accountancy, evaluating the effectiveness of its use and the resulting outcomes, and [21] who describe a financial web application that provides students with practice in content typical of these types of subjects such as balance sheets and profit and loss items. Another notable trend and the applications proposed by its exponents are the initiatives using spreadsheets, the use and impact of which are described in multiple publications. Our publication [10] is a comparative analysis of various systems already available based on spreadsheets, focusing on those that enable

exercises to be automatically corrected and assessed. Among our references we include [22–27].

Considering all these initiatives as interesting and useful and continuing in the line of innovative education, our contribution consists of describing the experience of **using** the *ACME_Business* tool. This initiative integrates different automatic e-learning correctors and has been implemented in the business administration subjects taught as part of all the technical degrees offered at the Polytechnic School of our university. The ultimate goal of our proposition is to increase student involvement and motivation and to create a learning experience that is both enjoyable and didactic. Generating individual exercises that serve to automatically correct and assess the practical activities conducted in the subject has a series of positive impacts.

The *ACME_Business* tool is self-developed from a formula that involves researchers from both the Department of Computer Science, Applied Mathematics and Statistics and others with different specialist experience and research and teaching expertise (from the areas of physics, chemistry and mathematics, among others). It was developed by university teaching and research staff for the main purpose of teaching Business Administration to Engineers. It incorporates different modules and automatic exercise generators and correctors, the most complex of which is the ACME_Spreadsheet.

The *ACME_Spreadsheet* sub-module enables the generation of multiple and varied exercises/activities with immediate correction. The teacher can shape the activities, programming formative and/or summative assessments as they choose, radically improving students' skills. Moreover, the tool continually updates the teacher on student activities and partial performance, providing valuable knowledge about which content or exercises require further attention. The automatic feature enables students to continuously monitor their learning process with each small fraction completed immediately corrected and feedback provided. Other characteristics are its flexibility and capacity for self-organisation, fully adapting to the user's availability to practice. Students send their answers via the web, immediately and automatically receiving a response, a valuable feature that allows the student to proceed further or to go back and correct the previous answer.

3. Methods

In this section, we describe how the course is organised and the data collection process and instrument.

3.1 Course organisation

The subject *Fundamentals of Business Administration* is compulsory on all the technical degrees taught. The aim is to train students in the basic theoretical and practical skills of key managerial and business organisation concepts and decision-making tools. Content is provided and practiced in three separate settings: theory (T), assisted practice (AP) and computer assisted practice (CAP). The theoretical content relevant to the field of business is provided by the teacher. This is followed by practical exercises addressed during AP, paralleled by CAP sessions where the theoretical content is practiced and assimilated, reinforcing the input from T and AP sessions and showing how spreadsheets can be used for these purposes. The basic features of the course are described in Table 1.

The course was designed to achieve specific **learning outcomes** formulated as competences, equivalent to what students *should be able to*:

- Describe, explain and apply fundamental concepts and relationships underlying accounting, economics, finance, management and managing information systems.
- Apply information technology and use information to support business processes and make decisions.
- Apply quantitative skills to analyse and solve business problems and discover opportunities.
- Communicate orally and in writing about business topics.
- Demonstrate proficiency in discipline-specific areas identified as specializations.

Although not explicitly stated, a series of other skills are also acquired through taking the subjects. One of the most noteworthy and relevant is **spreadsheet use** as a competence, which is especially trained and

Table 1. Summary of course characteristics

Characteristic	Value
Course duration	1 semester, 14 weeks (February – May)
Theory (T)	2 hours per week
Topics	Concepts in Management and Accounting Financial Reports and Statement Analysis
Assisted practice (AP)	1 hour per week
Computer assisted practice (CAP)	2 hours every 2 weeks (6 sessions)
Subject evaluation	25% CAP + 35% PAC + 40% Final exam

practiced in all the CAP sessions. Other competences are implicitly practiced in the same environment, such as:

- *Self-control or self-management*: a systematic, disciplined approach to coping with the daily workload and dealing with changing requirements and stressful situations [28: 92]. The teacher is present, providing the minimum information required to achieve the objectives of the session while encouraging students to make individual decisions about planning, managing and presenting their own solutions
- *Result orientation*: focusing attention on key objectives to obtain an optimum outcome [28:104]. Each session has a clear objective and a limited 2-hour duration. At the end of each session, students upload a file with the results obtained in the session.
- *Efficiency*: the ability to use time and resources efficiently to achieve the agreed outcome and to fulfil expectations by using methods, systems and procedures in the most effective way [28: 108]. Sessions are limited in time and each one has a unique procedure.

The main elements of the course organisation are captured in Fig. 1. As shown, the platform contemplates a series of tools organised by type of exercise and according to specific content. The basic ACME module is called *ACME_Business* (as opposed to *ACME_Mathematics*, *ACME_Physics*, etc.) and it has a specific sub-tool known as *ACME_Spreadsheet*, which is used within the context of the CAP sessions. All the tools are used to perform both formative and summative assessment apart from the true/false type exercises, which due to their relative ease are only used for formative assessment purposes.

The module is integrated into the Virtual Learn-

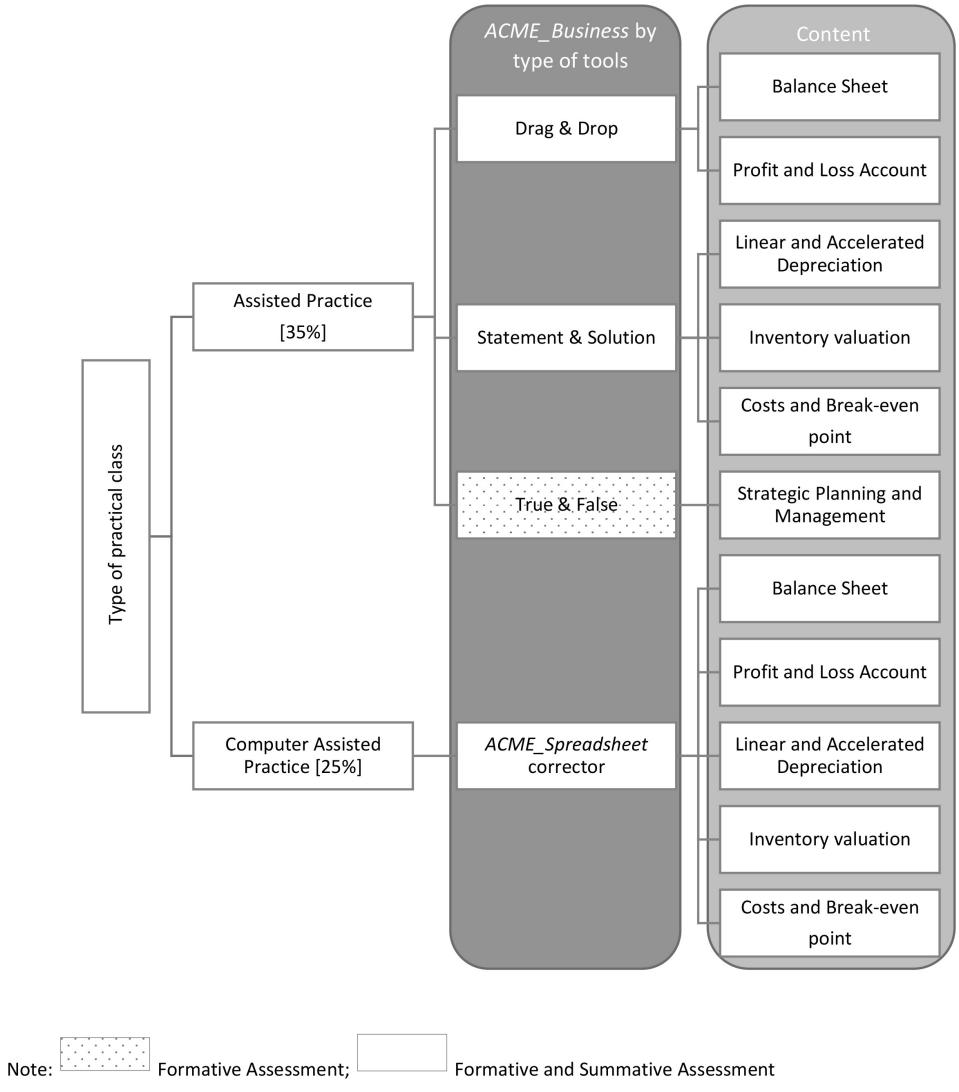

Fig. 1. Course organisation.

ing Management system. Virtual Learning Management solutions such as Moodle and others (when implemented) have a series of advanced features (true/false type questions, drag and drop type approaches, questionnaires and quizzes) which, despite providing a series of advantages, do not yet have the potential to generate personalized problem statements adapted to specific needs and complex situations and neither do they correct and provide users with immediate and personalized feed-back. By way of example, the Moodle drag and drop feature enables the correct result to be entered into a blank field, while the ACME module corresponding to mathematics [29] allows for a set of concepts and data which are compared, by means of a template, with the correct answer.

3.2 Data collection

Table 2 is a descriptive summary of the experience using the ACME platform's automatic spreadsheet correctors. Although ACME had already been implemented in the usual technical subjects taught in the technical degrees, during the 2013–2014 academic year it was piloted with a small group taking a business administration subject.

It was gradually extended in use to larger groups and other business administration subjects, reaching its apogee during the 2015/2016 academic year when 179 students used it. The figure for the 2016/2017 academic year was 154 students. The results presented here refer to the cohort of 333 students, if not otherwise specifically stated.

3.3 Validation of the perception evaluation questionnaire

Novel solutions often automatically trigger user perception evaluation surveys for the purpose of continuous improvement. Since the solution calls for specific questions, regular student satisfaction questionnaires were of no use, so a specific perception evaluation questionnaire was designed and applied. It was comprised of 20 items evaluated on a 5-point Likert-type scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). The questions were grouped into four areas of interest: (i) AP sessions, (ii) the spreadsheet corrector used in the CAP sessions, (iii) the *ACME_Spreadsheet* class experience, and (iv) the global *ACME_Business* experience. To ensure the maximum number of responses, students were asked to complete the survey at the end of the teaching period and as an attachment to the semester exam. The scale consistency was tested using Cronbach's Alpha test. The results are shown in Table 3.

The values obtained for Cronbach's Alpha showed good levels of internal consistency for each course considered in the analysis, both by thematic dimensions and globally, suggesting a relationship between the set of items as a group. All coefficients of reliability with values over 0.7 are considered as acceptable in most social science research.

4. Results

The academic results obtained by means of the ACME experience (Section 4.1) and its perceived usefulness (Section 4.2) are presented in this section.

4.1 Academic results

First, the students were organised into four groups according to the grades they achieved in the AP and CAP sessions, using the method of k-means. The distinction was made by separating the AP and CAP

Table 2. Number of participants and characteristics of subjects using *ACME_Business*

Subject with ACME environment evaluation	Fundamentals of Business Administration		
Teachers in the subject	1		
Pilot	2nd semester 2013/2014		
Semester/Academic year	2nd 2015/2016, 2016/2017		
	Students enrolled	Students responding to the survey	Students examined
Academic year 2015/2016	179	128 [71%]	155
Academic year 2016/2017	154	137 [89%]	141

Table 3. Participants and characteristics of subjects using *ACME_Business*

		Values for Cronbach's Alpha		
	No of Items	**2015/16**	**2016/17**	**All**
Assisted Practice by type of content	6	0.750	0.843	0.804
Computer Assisted Practice by spreadsheet corrector	6	0.870	0.934	0.914
ACME_Spreadsheet corrector experience	5	0.749	0.865	0.831
Global *ACME_Business* experience	3	0.720	0.797	0.764
All items	20	0.896	0.938	0.925

Table 4. Grouping students by mean grades and types of sessions (CAP and AP)

2015/16 academic year				2016/17 academic year			
	Cluster Centres				Cluster Centres		
Cluster	CAP	AP	Cases	Cluster	CAP	AP	Cases
H-H	8.07	7.73	71	H-H	7.74	7.69	56
H-L	7.29	4.87	26	H-L	6.22	4.88	36
L-H	3.1	6.95	44	L-H	2.38	6.73	32
L-L	1.78	2.8	14	L-L	1.22	3.61	17
			155				141

Note: The grades take values from 0 (low) to 10 (excellent).

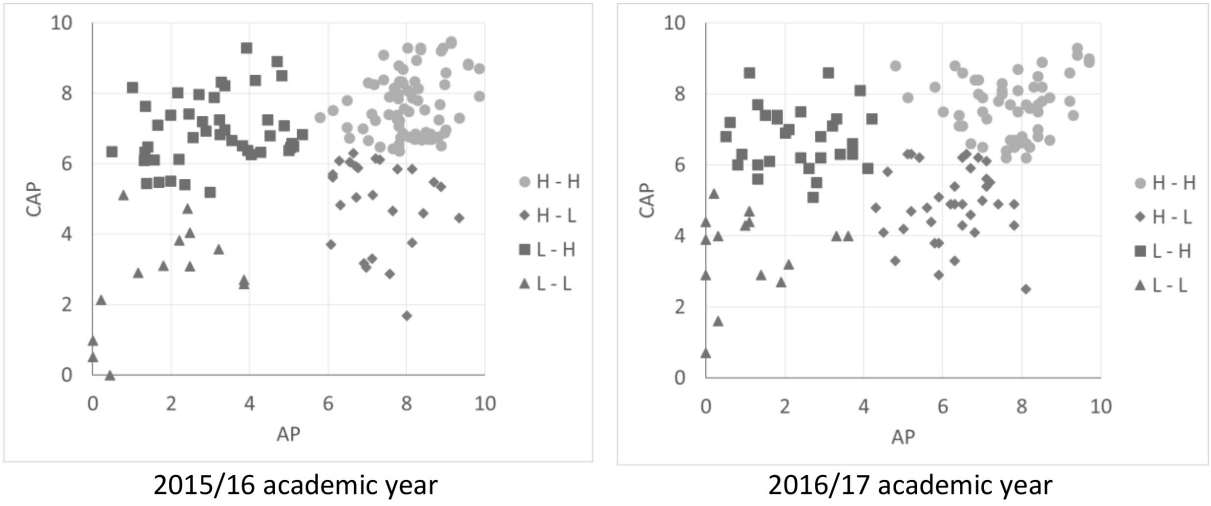

Fig. 2. Groups according to CAP and AP.

Table 5. Group characteristics (descriptive statistics)

		2015/16 academic year					2016/17 academic year				
Grades		N	Mean	Std. Deviation	Min	Max	N	Mean	Std. Deviation	Min	Max
CAP	H-H	71	8.0660	0.83798	5.79	9.85	56	7.7357	1.08233	4.80	9.70
	H-L	26	7.2918	0.91264	6.08	9.35	36	6.2167	0.97673	4.30	8.10
	L-H	44	3.0957	1.34066	0.47	5.34	32	2.3813	1.08670	0.50	4.20
	L-L	14	1.7760	1.36252	0.00	3.85	17	1.2235	1.24475	0.00	3.60
	Total	155	5.9571	2.71895	0.00	9.85	141	5.3475	2.77295	0.00	9.70
AP	H-H	71	7.7287	0.88875	6.37	9.48	56	7.6946	0.84669	6.20	9.30
	H-L	26	4.8691	1.26139	1.69	6.30	36	4.8806	1.01103	2.50	6.30
	L-H	44	6.9514	0.96977	5.20	9.30	32	6.7281	0.86070	5.10	8.60
	L-L	14	2.8037	1.50099	0.00	5.11	17	3.6118	1.16505	0.70	5.20
	Total	155	6.5835	1.87307	0.00	9.48	141	6.2645	1.75231	0.70	9.30
Exam	H-H	71	5.3420	2.25264	1.07	9.73	56	6.8000	1.45877	4.00	9.70
	H-L	26	4.4632	1.94932	1.35	7.93	36	5.1194	1.69618	0.40	8.40
	L-H	44	4.6355	1.88702	0.83	7.80	32	5.3656	1.97298	1.00	9.30
	L-L	14	2.7990	1.70274	0.20	6.48	17	2.3765	2.67431	0.00	8.80
	Total	155	4.7644	2.16506	0.20	9.73	141	5.5121	2.26638	0.00	9.70
Final	H-H	71	6.8137	1.23559	2.70	9.38	56	7.3518	0.87115	6.00	9.20
	H-L	26	5.3231	1.02691	3.55	7.07	36	5.2083	1.18451	0.40	6.90
	L-H	44	5.0672	1.03663	2.81	7.41	32	5.0156	1.18297	0.90	7.50
	L-L	14	2.5558	1.28262	0.19	5.00	17	2.1588	1.62637	0.20	5.70
	Total	155	5.6833	1.70668	0.19	9.38	141	5.6482	2.01039	0.20	9.20

Table 6. Test of Homogeneity of Variances

	2015/16 academic year				2016/17 academic year			
	Levene Statistic	**df [1]**	**df [2]**	**Sig.**	**Levene Statistic**	**df [1]**	**df [2]**	**Sig.**
CAP	7.747	3	151	0.000	0.450	3	137	0.717
AP	2.771	3	151	0.044	0.717	3	137	0.543
Exam	2.042	3	151	0.110	5.560	3	137	0.001
Final	1.135	3	151	0.337	3.295	3	137	0.022

Table 7. Between Group and Within Group differences

		2015/16 academic year					2016/17 academic year				
CAP		Statistic[a]	df [1]	df [2]	Sig.		Statistic[a]	df [1]	df [2]	Sig.	
	Welch	52.128	3	46.594	0.000		84.364	3	50.069	0.000	
	Brown-Forsythe	62.386	3	69.580	0.000		79.278	3	58.674	0.000	
		Sum of Squares	df	Mean Square	F	Sig.	Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	967.077	3	322.359	283.995	0.000	917.274	3	305.758	263.091	0.000
	Within Groups	171.398	151	1.135			159.218	137	1.162		
	Total	1138.476	154				1076.492	140			
AP		Statistic[a]	df [1]	df [2]	Sig.		Statistic[a]	df [1]	df [2]	Sig.	
	Welch	224.607	3	43.391	0.000		235.055	3	54.236	0.000	
	Brown-Forsythe	238.804	3	58.739	0.000		248.441	3	81.915	0.000	
		Sum of Squares	df	Mean Square	F	Sig.	Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	375.494	3	125.165	114.685	.000	309.996	3	103.332	118.082	0.000
	Within Groups	164.797	151	1.091			119.887	137	.875		
	Total	540.291	154				429.883	140			
Exam		Statistic	df [1]	df [2]	Sig.		Statistic[a]	df [1]	df [2]	Sig.	
	Welch	74.796	3	42.534	0.000		100.786	3	52.837	0.000	
	Brown-Forsythe	83.905	3	49.280	0.000		104.738	3	73.252	0.000	
		Sum of Squares	df	Mean Square	F	Sig.	Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	80.860	3	26.953	6.349	0.000	266.270	3	88.757	26.852	0.000
	Within Groups	641.012	151	4.245			452.839	137	3.305		
	Total	721.872	154				719.110	140			
Final		Statistic[a]	df [1]	df [2]	Sig.		Statistic[a]	df [1]	df [2]	Sig.	
	Welch	7.618	3	49.104	0.000		19.736	3	50.523	0.000	
	Brown-Forsythe	7.285	3	103.156	0.000		20.926	3	55.340	0.000	
		Sum of Squares	df	Mean Square	F	Sig.	Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	247.740	3	82.580	62.092	0.000	389.281	3	129.760	100.692	0.000
	Within Groups	200.825	151	1.330			176.551	137	1.289		
	Total	448.566	154				565.832	140			

a. Asymptotically F distributed.

grades into high and low. Hence, the H-H group had obtained high grades in both settings; the H-L group had a high CAP grade but a low AP grade; the L-H group had a low mean grading in the CAP sessions but a high AP grade; and the L-L group had obtained low grades in both types of sessions. Table 4 shows the specific values and the number of students in each group.

The centres of the four groups are similar between academic years, while the largest group is the H-H group and the smallest is the L-L group. Fig. 2 shows the distribution of the different groups during the academic years.

Table 5 contains the basic descriptive values of the mean and standard deviation of grades corresponding to the CAP and AP sessions, the exam and the final result for the different academic years. It is interesting to observe that the H-H group is the largest one and that the mean exam and final grades of the students in this group are higher than those of all the other groups. The mean values for the exam grade and the final grade are similar for the H-L and L-H groups. The L-L group has the lowest values of all the groups. The CAP and AP grades are related to the classification of groups.

A one-way ANOVA test was performed to further verify the observed differences between the means. The test of homogeneity of variances (*Levene statistic*) showed that homogeneity of variances could not be assured in all the cases (Table 6).

As observed, the results differ between academic years. For the 2015/2016 academic year there is homogeneity of variances between the exam grade and the final grade, while for the 2016–2017 academic year there is homogeneity of variances for the CAP grade and the AP grade. Since there was no way to guarantee homogeneity of variances for all the cases beyond the F statistics we applied the *Welch* and *Brown-Forsythe test*, which shows significant differences for all the cases (p-value < 0.05) (see Table 7).

We proceeded with a Post Hoc test to detect which of the four groups showed significant differences between the CAP and the AP grades, which gave unsurprising results considering that these were the variables used to cluster students and form the groups. Regarding the mean grade of the variable exam for each of the groups, we observed that for the 2015/16 academic year there were significant differences between the H-H and L-L groups and between the L-H and the L-L groups, while this trend was not observed between the other groups. Regarding the 2016/17 academic year, there were significant differences between all the groups except for the groups H-L and L-H. Last, if we focus on the mean grade of the variable final, significant differences were detected in all the cases except for the groups H-L and L-H. These results were contrasted with two additional tests, one assuming homogeneity of variances (*Bonferroni Test*) and the other assuming no homogeneity of variances (*Tamhane Test*). The results are shown in Table 8 and Table 9.

4.2 Perception results

As mentioned in section 3.3, innovative solutions mandatorily require perception evaluation. Using a specifically designed questionnaire we were able to capture students' perceptions of the technical, didactic and subject aspects, and of the global experience. Figs. 3, 4, 5 and 6 are visual representations of the data collected.

The overall perception of all the evaluated aspects was positive, with most items at over 70% agreement levels, calculated from the sum of the "Agree" and "Totally agree" response categories.

Five items reach 85% (and above) agreement levels: "*ACME exercises are suited to the content of the subject*" (86%), "*The teacher was willing to help solve technical problems*" (87%), "*It served to tell me if I was calculating correctly or not*" (85%) and "*It improved my ability to use spreadsheets*" (85%), "*The Balance Sheet corrector was helpful*" (86%).

Table 8. Multiple Comparisons—*Bonferroni* Test

	2015/16 academic year				2016/17 academic year			
	Sig.	H-L	L-H	L-L	Sig.	H-L	L-H	L-L
CAP	H-H	**1.11E-02***	**2.67E-53***	**5.81E-44***	H-H	**2.87E-03***	**9.73E-32***	**1.25E-45***
	H-L		**2.39E-33***	**1.48E-32***	H-L		**4.91E-29***	**6.83E-47***
	L-H			**5.15E-04***	L-H			**5.08E-09***
AP	H-H	**8.75E-23***	**9.41E-04***	**7.31E-34***	H-H	**4.85E-20***	**5.50E-05***	**8.57E-32***
	H-L		**1.31E-12***	**1.01E-07***	H-L		**1.37E-12***	**4.40E-05***
	L-H			**1.84E-25***	L-H			**1.25E-27***
Exam	H-H	3.88E-01	4.55E-01	**2.51E-04***	H-H	**1.20E-06***	**5.91E-06***	**3.40E-14***
	H-L		1.00E+00	9.59E-02	H-L		1.00E+00	**3.06E-03***
	L-H			**2.54E-02***	L-H			**1.74E-04***
FINAL	H-H	**4.92E-07***	**3.34E-12***	**1.27E-24***	H-H	**3.29E-13***	**4.81E-15***	**1.24E-33***
	H-L		1.00E+00	**1.29E-10***	H-L		1.00E+00	**1.94E-15***
	L-H			**2.78E-10***	L-H			**2.52E-14***

* The mean difference is significant at the level 0.05.

Table 9. Multiple Comparisons—*Tamhane* Test

	2015/16 academic year				2016/17 academic year			
	Sig.	H-L	L-H	L-L	Sig.	H-L	L-H	L-L
CAP	H-H	**2.96E-03***	**0.00E+00***	**2.63E-10***	H-H	**1.80E-02***	**3.90E-13***	**2.66E-15***
	H-L		**0.00E+00***	**1.31E-10***	H-L		**0.00E+00***	**0.00E+00***
	L-H			**2.68E-02***	L-H			**4.68E-09***
AP	H-H	**1.18E-11***	**2.60E-04***	**3.36E-08***	H-H	**2.82E-09***	**3.73E-03***	**4.18E-11***
	H-L		**3.63E-08***	**1.30E-03***	H-L		**9.10E-11***	**1.98E-05***
	L-H			**1.77E-07***	L-H			**0.00E+00***
Exam	H-H	3.33E-01	3.66E-01	**4.39E-04***	H-H	**2.48E-03***	**4.78E-03***	**1.79E-05***
	H-L		1.00E+00	5.19E-02	H-L		9.95E-01	**4.47E-03***
	L-H			**1.33E-02***	L-H			**3.95E-05***
FINAL	H-H	**1.14E-06***	**5.48E-12***	**6.36E-09***	H-H	**6.12E-06***	**2.11E-06***	**7.19E-10***
	H-L		0.901106	**3.17E-06***	H-L		0.98532	**1.97E-12***
	L-H			**1.45E-05***	L-H			**1.77E-12***

* The mean difference is significant at the level 0.05.

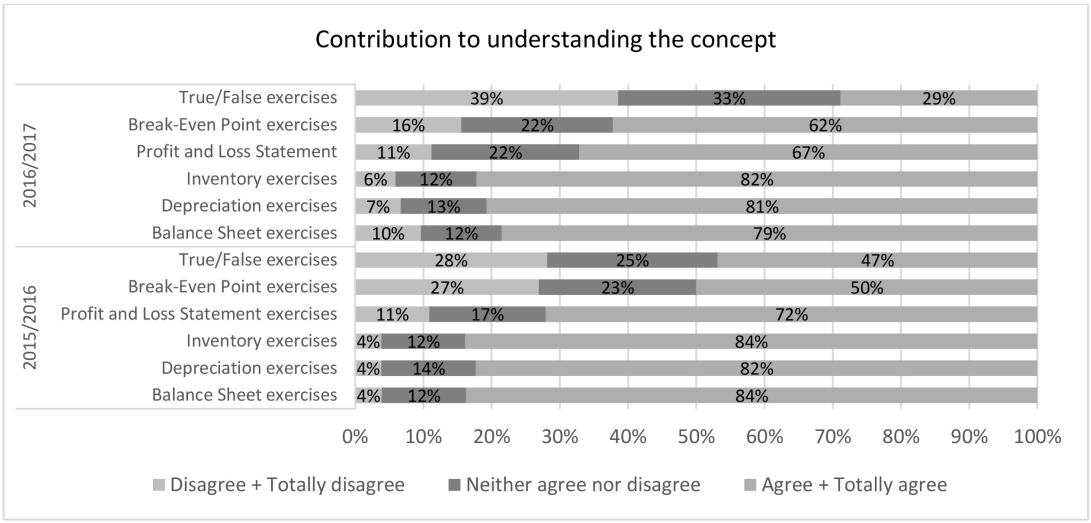

Fig. 3. Student perception of the Assisted Practice by type of content.

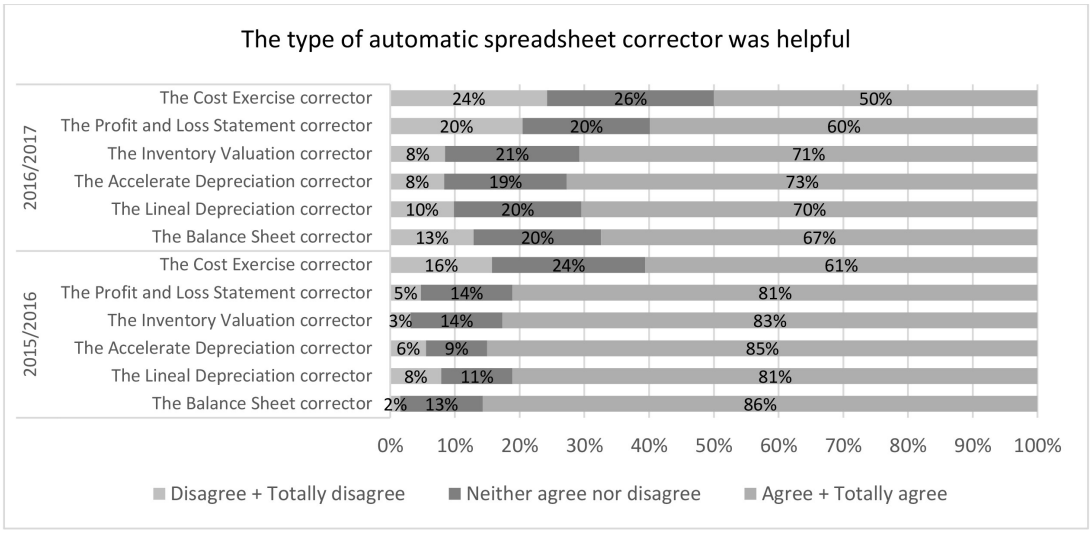

Fig. 4. Student perception of the Computer Assisted Practice by spreadsheet corrector.

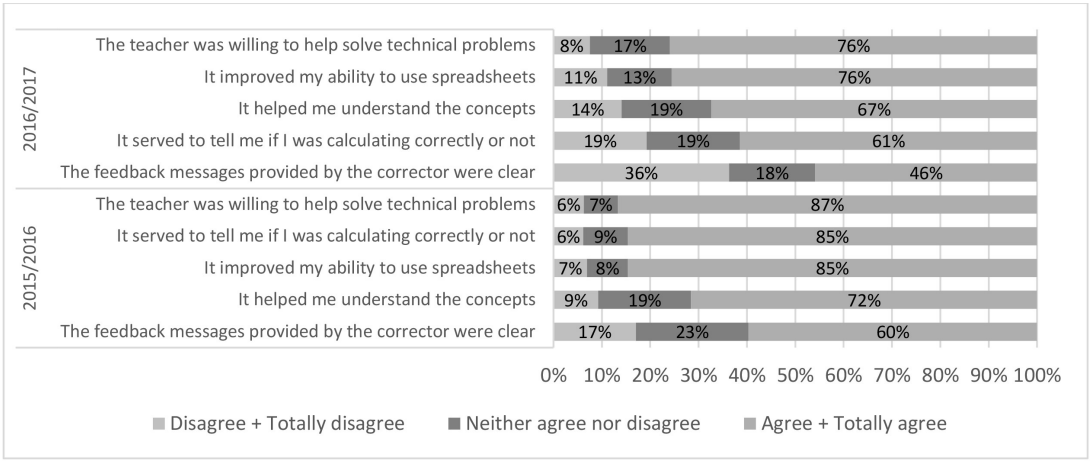

Fig. 5. Student perception of the ACME_Spreadsheet corrector experience.

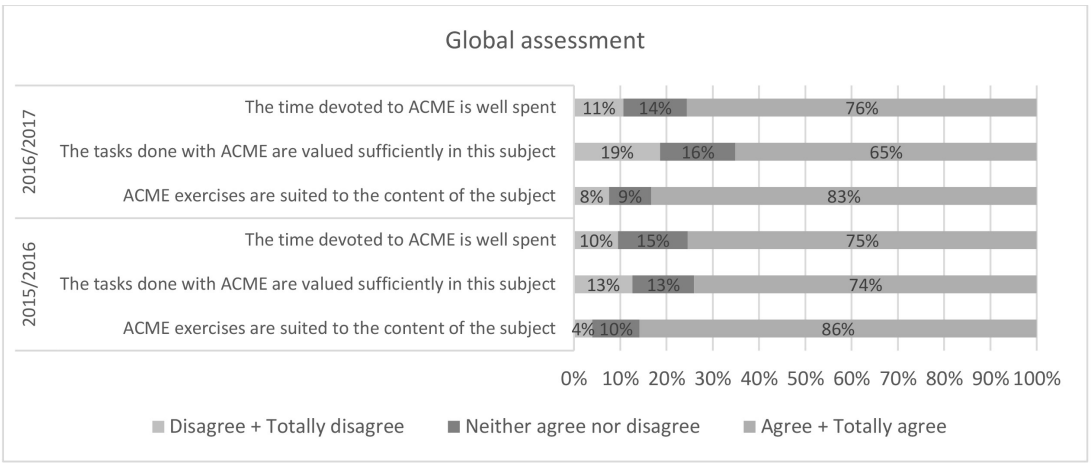

Fig. 6. Student perception of the global *ACME_Business* experience.

Among the items with the highest levels of disagreement (shown in brackets), which are potential inputs for further improvement or reformulation, we find "*True/False exercises contributed to understanding the concept*" (39%), "*Break-even point exercises contributed to understanding the concept*" (27%), "*Feedback messages provided by the corrector were clear*" (36%), "*The Cost exercise corrector was helpful*" (24%), "*The Profit and Loss Statement corrector was helpful*" (20%).

The change in tendencies in the evaluated items from one academic year to another is also noteworthy. The overall trend between the 15/16 and 16/17 academic years was increasing disagreement with rather negative items. This may be explained by how the subject was evaluated, as this was the only aspect that was modified between the two academic years, further suggesting that the higher the level of demand for the subject, the more negative the perception of the tool used. Last, and as possible additional proof of motivation and satisfaction, students asked for more ACME activities and that their weighting in the final evaluation be increased, a further reflection of student awareness of the usefulness of the tool.

5. Discussion

In this paper we describe the experience of using an automatic e-learning solution and its impact on both academic results and student perception aspects within the context of an early degree subject, Business Administration, which is mandatory for all technical/engineering degrees.

In terms of *academic performance*, our results show that the proposed solution improves both partial and overall evaluation grades. The *learning experience performance*, which can be read from the perception evaluation, has a rather positive resonance, hinting of further improvements. Students' requests for more activities using the same tool and approach are sound evidence of their level of

satisfaction. While the knowledge gained is important and is still a core issue in HEI training today, the competence-oriented approach is also visible. The proposed solution is perceived as useful in training the skill of using spreadsheets (76% and 85%), a cross-cutting skill that is highly valued in both academic and business settings.

Current limitations equating to future improvements are related to being able to self-assign exercises, enabling students to choose as many and as varied exercises as they wish, providing even greater autonomy and self-management compared to the current solution. Further sophistications include a "smart" learning plan provided by the system based on historical data and performance indicators, as well as an even higher integration into the LMS, especially for grade computing and export in the academic record.

6. Conclusions

As an e-learning system for teaching business subjects to engineers, the *ACME_Business* module is innovative both as a solution and as an educational approach. Like any novel *solution*, it has followed a regular innovation path through the different stages of design, prototyping and pre-testing, implementation and continuous improvement. It is the culmination of several years' work and consists in a long-lasting experience gathering a multidisciplinary team in a collaborative formula. Framed within a global family of applications that fall under the umbrella term Continuous Evaluation and Educational Improvement (ACME), it had been implemented as a solution for motivating engineering students in non-specialty subjects and as a way of optimising the work of educators in managing early-stage high volume classes of future engineers.

From an *educational approach* perspective, implementing *ACME_Business* in class settings is set apart from other strategies since it generates a highly valuable e-learning experience from several perspectives and in terms of the following associations: (i) *student-educator*, with both groups gaining valuable benefits from using the novel solution compared to more traditional teaching/learning approaches, (ii) *present-future*, where a competence trained in the present is highly likely to be used in future professional situations irrespective of the labour market sector, (iii) *knowledge-competence*, meaning that using *ACME_Business* helps to transmit and consolidate both knowledge—fundamentals of business administration—and competence—spreadsheet use, (iv) *university-business*, where the approach used in a university setting is equipping future professionals with one of the competences most used and valued by businesses and firms.

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