








Multidimensional quantitative analysis of a 360-degree feedback surveyed in practical industrial engineering sessions

Estudio cuantitativo multidimensional de la experiencia de evaluación 360 encuestada en prácticas de ingeniería industrial

Estudo quantitativo multidimensional da experiência de avaliação 360 inquirida em aulas práticas de engenharia industrial

对工业工程实践进行的360度评估调查的多维度定量研究

دراسة كمية متعددة الأبعاد لتجربة تقييم 360 التي تم مسحها في ممارسات الهندسة الصناعية

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Abstract

Initiative and proactiveness shown by students during engineering lectures is usually very limited. However, unlike in theoretical lectures, students usually show high levels of interest in practical laboratory sessions. In order to address increasing dropout from engineering courses, as well as decreased enrollment, the present study aims to quantitatively analyze the impact of a 360-degree feedback survey for evaluating practical sessions. Analysis was conducted overall and as a function of different groupings in industrial engineering students. The aim of this was to address a number of objectives. Firstly, the study aimed to engage students in the evaluation process and, secondly, identify satisfaction with 360-degree feedback as a function of different groupings, whilst, at the same time, gathering opinions about the fairness of each evaluation type. To this end, a methodology based on the application of 360-degree feedback was applied and a 23-question survey was administered. The following three stages were followed for the 360-degree feedback evaluation process: co- (between students), self- (the student themselves) and hetero-evaluation (lecturer). Initially, a questionnaire was designed and validated using confirmatory factor analysis. Responses were analyzed as a function of 4 groups: module (one first- and one third-year module), evaluation type, sex (male or female) and degree level (BSc or MSc). The most appropriate weighting to be applied to each evaluation in order to produce a final overall score was also analysed. This suggested optimal values of 50%, 30% and 20% for the hetero-, co- and self-evaluations, respectively. Additionally, outcomes revealed a high degree of satisfaction for all analysed groupings and pointed to a high level of maturity in participating students.

Keywords: Survey, satisfaction, confirmatory factor analysis, industrial engineering.

Resumen

La iniciativa y la proactividad del alumnado durante el desarrollo de las clases en ingeniería es normalmente muy limitada. No obstante, a diferencia de en clases teóricas, el alumnado suele mostrar mayor interés en las prácticas de laboratorio de las asignaturas. Debido a que el aumento del abandono en las carreras de ingeniería, así como la disminución de matriculados, es un hecho que se viene observando con cada vez más frecuencia, este estudio tiene como fin el analizar cuantitativamente el impacto de una herramienta de evaluación 360 grados encuestada en la evaluación de prácticas, en distintos grupos estudiantiles de la rama de la ingeniería industrial. Con esto se pretende lograr varios objetivos: por un lado, implicar al estudiante en el proceso de evaluación y, por otro, conocer su grado de satisfacción de distintos grupos con la evaluación 360 grados, así como su opinión sobre la ponderación justa de cada evaluación. Para ello, se presenta una metodología basada en la aplicación de la evaluación 360 grados y un diseño de encuesta con 23 preguntas. Las etapas del proceso de evaluación 360 grados fueron tres: co- (entre estudiantes), auto- (por el propio estudiante) y hetero-evaluación (por el docente). Inicialmente, se diseñó un cuestionario, validado mediante análisis factorial confirmatorio, y se procedió al análisis de las respuestas en base a 4 agrupaciones seleccionadas: dos asignaturas de primeros y últimos cursos, modalidad de evaluación, sexo (hombre o mujer) y ciclo (Grado o Máster). También se ha analizado la mejor ponderación en la calificación final para cada evaluador, proponiéndose como óptimos los valores 50%-30%-20% para la hetero-, co- y autoevaluación, respectivamente. Adicionalmente, los resultados arrojaron un elevado grado de satisfacción por parte de los grupos analizados a través de la encuesta y reflejando la maduración del estudiante.

Palabras clave: Encuesta, satisfacción, análisis factorial confirmatorio, ingeniería industrial.

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Resumo

A iniciativa e a proatividade dos alunos durante as aulas de engenharia são geralmente muito limitadas. No entanto, ao contrário do que acontece nas aulas teóricas, os alunos tendem a mostrar mais interesse pelas práticas laboratoriais das disciplinas. Dado que o aumento de desistências nos cursos de engenharia, bem como a diminuição de matrículas, é um facto que se tem vindo a observar com cada vez mais frequência, este estudo tem como objetivo analisar quantitativamente o impacto de uma ferramenta de avaliação de 360 graus inquirida na avaliação de aulas práticas, em diferentes grupos de estudantes no ramo da engenharia industrial. Pretende-se, assim, atingir vários objetivos: por um lado, envolver o estudante no processo de avaliação e, por outro, conhecer o seu grau de satisfação de diferentes grupos com a avaliação de 360 graus, bem como a sua opinião sobre a ponderação justa de cada avaliação. Para isso, apresenta-se uma metodologia baseada na aplicação da avaliação de 360 graus e a elaboração de um questionário com 23 perguntas. As fases do processo de avaliação de 360 graus eram três: co- (entre estudantes), auto- (pelo próprio estudante) e heteroavaliação (pelo docente). Inicialmente, foi elaborado um questionário, validado por análise fatorial confirmatória, e procedeu-se à análise das respostas com base em 4 grupos selecionados: duas disciplinas dos primeiros e últimos anos, modo de avaliação, sexo (masculino ou feminino) e ciclo (Licenciatura ou Mestrado). Foi também analisada a melhor ponderação na nota final para cada avaliador, propondo-se como ótimos os valores 50%-30%-20% para a hetero-, co- e autoavaliação, respetivamente. Além disso, os resultados revelaram um elevado grau de satisfação por parte dos grupos analisados através do questionário, o que reflete a maturidade do estudante.

Palavras-chave: Questionário, satisfação, análise fatorial confirmatória, engenharia industrial.

摘要

在工程课上，学生表现出来的主动性和积极性往往不高。但跟理论课相反，在学科实验课上学生常常表现出更多的兴趣。考虑到工程专业逐年提升的弃学率，和逐年下降的注册率，该研究希望对一测量工具的影响进行定量分析。该工具可以在360度的范围内对工业工程专业的不同学生群体进行实践评估，以此来达成以下目标：一让学生参与到评估过程；二通过360度评估了解不同群体的满意度以及他们对每项评估权重的意见。为了实现上述目标，研究使用360度评估方法和包含23个问题的问卷调查。360度评估过程分为三个阶段：相互评估（学生与学生之间）、自我评估（由学生自己进行）和异体评估（由老师进行）。首先设计了一个通过验证性因素分析的问卷，然后对问卷答案进行分析。我们将答案分成四组：低年级和高年级的两门课程、评估类型、性别（男或女）以及学历周期（本科或研究生）。除此之外我们还对每项评估员最终打分的最优权重进行了分析，提出异体、相互和自我评估阶段的最佳值为50%、30%和20%。最后问卷结果还显示出不同分析群体的满意度都很高，这也一定程度上反映了学生的成熟度。

关键词: 问卷、满意度、验证性因素分析、工业工程

ملخص

عادة ما تكون مبادرة الطلاب واستباقيتهم أثناء تطوير فصول الهندسة محدودة للغاية. ومع ذلك، على عكس الفصول النظرية، يُظهر الطلاب عادةً اهتمامًا أكبر بالممارسات المختبرية للموضوعات. نظرًا لأن الزيادة في عدد المتسربين من الدورات الهندسية، فضلاً عن انخفاض الالتحاق، هي حقيقة يتم ملاحظتها أكثر فأكثر تهدف هذه الدراسة إلى التحليل الكمي لتأثير أداة تقييم 360 درجة في تقييم الممارسات، في مجموعات طلابية مختلفة لفرع الهندسة الصناعية. وبهذا فإن الهدف من ذلك هو تحقيق العديد من الأهداف من ناحية إشراك الطالب في عملية التقييم، ومن ناحية أخرى معرفة درجة رضاهم عن المجموعات المختلفة بالتقييم 360 درجة، وكذلك رأي حول التوزيع العادل لكل تقييم (لهذا يتم تقديم منهجية تستند إلى تطبيق التقييم 360 درجة وتصميم المسح مع 23 سؤالاً). كانت هناك ثلاث مراحل من عملية التقييم بزوايا 360 درجة: مشتركة (بين الطلاب ذاتي) من قبل الطالب نفسه (وتقييم غير متجانسة) من قبل المعلم (في البداية، تم تصميم استبيان، والتحقق من صحته من خلال تحليل عامل التأكيد، وتم تحليل الردود على أساس 4 مجموعات مختارة: موضوعان من العاملين الأول والأخير، وطريقة التقييم، والجنس) ذكر أو أنثى (والدورة) الدرجة أو الماجستير. (تم أيضاً تحليل أفضل ترجيح في الدرجة النهائية لكل مقيّم، واقترح القيم المثلثية من 50%-30%-20% للتقييم غير المتجانسة، والمشاركة، والتقييم الذاتي، على التوالي. بالإضافة إلى ذلك، أظهرت النتائج درجة عالية من الرضا من جانب المجموعات التي تم تحليلها من خلال الاستبيان وتعكس نصح الطالب.

الكلمات الدالة: مسح رضا، تحليل عامل التأكيد، الهندسة الصناعية

Introduction

The basic aim of the evaluation process is to assist in the promotion of better training for future professionals, in order to equip them to take on future challenges. To this end, evaluation constitutes one of the key elements of curricular design, being the process through which the degree to which the stated objectives

of different training processes are met is examined and verified. All teaching-learning processes should go hand in hand with procedures designed to identify the degree to which meaningful learning has been achieved.

The term evaluation implies multiple factors of a diverse nature. This has led to the emergence of numerous definitions of the

term, all of which carry different connotations. A landmark reference is provided by Ralph Tyler (Tyler, 1942), author of the first systematic methods of educational evaluation during the 30s and 40s, whilst working at Ohio State University. Such methods considered that “*the evaluation process is essentially a process that determines to what extent educational objectives have actually been met through teaching programs and curricula*”. In this sense, such processes require different stages, starting with the setting and ordering of defined goals and ending with the gathering and examination of data in terms of the achievement level reached. This has been the go-to method applied for decades in the educational system and used as an essential tool by teaching staff. Nonetheless, it does not consider neither the interests and attitudes of students, nor evaluation of the learning system itself, instead focusing solely on goals and academic achievement Glass and Ellet (1980) and Wortman (1983) conceived a broader concept, providing greater versatility and flexibility, by introducing ways and means: “*A set of theoretical and practical activities, although lacking a generally accepted paradigm, with a large variety of models and in which different approaches and methods are recognised, being considered apt for evaluation*”. House (1993) introduced a social component, progressing the conception from one of an activity engaged in by academics during their spare time, to that of a professional activity that is integrated throughout all spheres of the teaching process: (1) through dealing with students and, (2) through dealings with the program itself or the teaching management approach.

The proliferation of evaluation models during the 80s and 90s indicates the growth and complexity of evaluation processes, with substantial differences being found to exist between different authors. Bravo Arteaga et al. (2000) summarise the most commonly cited criticisms of traditional evaluation models, with the following most standing out: *They only measure stated knowledge and not procedural knowledge* (Mehrens, 1992); *They*

are based on outcome and not on process (Mumford, Baughman, Supinski & Andersen, 1998); *They fail to adequately cover the domain under evaluation* (Mehrens, 1992); *Various abilities and, even, intelligences are not evaluated* (Powell, 1990); *They are too far removed from true contextual demands* (Mumford, Baughman, Supinski & Anderson, 1998). These criticisms are grounded in the fact that no two individuals are the same, they do not reach aims in the same way, and their speed and style of learning and learning needs are different, whilst recent evaluation models, based on skill acquisition, seek proof and ratings regarding student progress towards expected learning outcomes. The way in which models handle students, therefore, must move from their inclusion as passive subjects, subjected to actions under strict rules, to a more active consideration, in which they organise and structure their own knowledge through continuous and systematic follow-up of their progress towards reaching goals and overcoming challenges. In light of all of the above, within the teaching experience presented here, students take on an important role in the evaluation process pertaining to the delivery of subjects, in which their experience is used with student opinions forming part of the final evaluation.

This aforementioned approach has been taken in the industrial setting within an engineering school as a means to reach the aims outlined below. Further, in recent years a concerning decline has been observed in the number of students enrolling in engineering courses. This issue has been highlighted in a number of different informative reports (Silió, 2019; Stegmann, 2019; Servimedia, 2019), with a drop of as much as 30% being seen in the last 20 years (Silió, 2019). Amongst the potential causes, one of the most noteworthy is that the world of work is not set up to be able to adequately reimburse and compensate the challenges inherent to these types of courses (Servimedia, 2019). This issue has been described in previously conducted studies conducted to determine the level of efficiency present in engineering occupational settings in

Spain (Castillo-Martín, 2021). In this sense, efficiency is understood as a combination of rentability (employability, salary, satisfaction and engagement) and effort (average years of study required, cost of study and average grades). Another noteworthy finding that reflects the issue being discussed in the high rate of dropout, with this tending to be highest in Engineering and Architecture (López-Cózar-Navarro et al., 2020). The Spanish University Rectors Conference (CRUE) published the damning figure of 22% dropout from Engineering and Architecture during the 2017/2018 academic year (Hernández & Pérez, 2019).

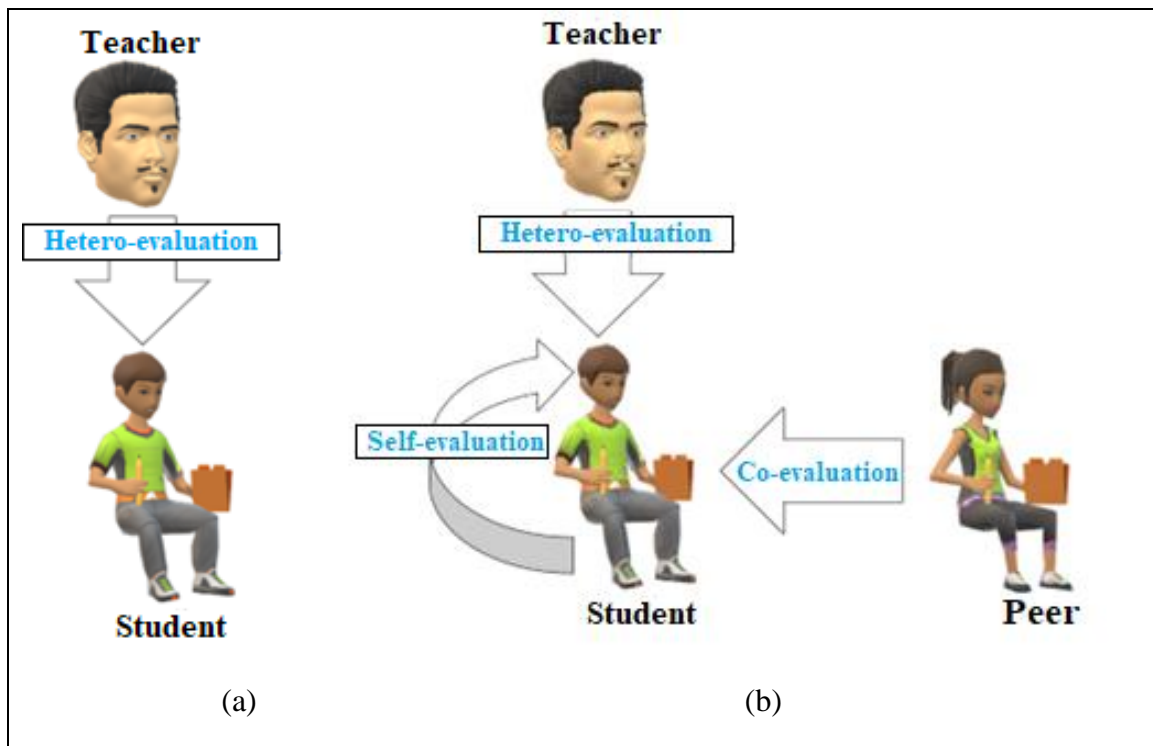
This issue proves that it is highly necessary to find alternatives that make engineering courses more attractive to students, without losing quality in delivery, in order to be able to continue to produce competent engineers at the same time as getting students to learn without causing frustration. A number of studies have pointed to student satisfaction when urging higher enrolment, reduced absenteeism and better student retention (Schertzer & Schertzer, 2004, Rodríguez et al, 2003). Some studies to analyse dropout rate report that, in order to decrease student dropout, it is helpful to conduct a personalised assessment of student learning needs throughout the period of their study, at the same time as involving them through active and innovative learning in the classroom (López-Cózar-Navarro et al., (2020); García et al., 2016). It is, therefore, reasonable to expect that an evaluation process that engages and gives a voice to those under evaluation will be well received by students, especially, given that increased classroom participation, interaction with teachers and alternative task performance have a positive

impact on reducing dropout rate (García et al., 2016). In this sense, peer evaluation is identified as the most influential factor when it comes to improving some skills, such as teamwork (Petkova et al., 2021). Nonetheless, at first, some concerns can be expressed with regards to this methodology, such as variability in evaluation on behalf of students or their lack of training. In support of this, Martin and Locke (2022) highlight that peer evaluation is a consensus approach. Despite this, Mumpuni et al., (2022) defend this approach, arguing that this type of evaluation is objective and based on study outcomes.

The aim of the study presented in the present paper is to squeeze as much benefit as possible out of the evaluation of student practice (and, consequently, the subject under study). In addition to conducting an evaluation of themselves and their teachers, participants performed a peer evaluation in order to provide a 360-degree view of the teaching-learning process. This is known as “360-degree evaluation” (or, more commonly, *360-degree feedback* in English). Figure 1 presents a diagram comparing traditional evaluation and the 360-degree evaluation described above.

The present manuscript proposes a 360-degree evaluation process, in which evaluation is conducted in consideration of a series of hugely important groupings, such as analysis of its application as a function of sex, maturity with regards to the academic year being undertaken and the method being used to evaluate practice in subject delivery. The present study enables valuable responses to be gathered as a function of these groupings, enabling the identification of strengths and weaknesses of the 360-method within each one of these “academic groups”.

Figure 1. (a) Traditional or standard evaluation; (b) 360-degree feedback.



In order to conduct evaluation, certain criteria and achievement levels (rubrics) must be available through with evaluation can be quantified. In the present study, a further effort is made to gather information about the satisfaction experienced by the different examined groups, in this way, making them complicit in the study and, thus, making it possible to achieve greater personalisation of the rubrics. According to numerous authors (e.g. Lévy-Leboyer, 2004; Bizquerra et al., 2006), evaluation of an individual's skills is based on different sources and corresponds to three phases:

1. *Hetero-evaluation* (teacher). Traditional method in which teachers evaluate a task. In order to prevent evaluative disparity, homogeneity is sought in the evaluation criteria applied to the three evaluation types through the use of the exact same rubric in each of the three approaches taken in 360 feedback (Mertler, 2001). Basurto-Mendoza et al., (2021) state that this type of evaluation “sustains, guides, accompanies and strengthens” all other evaluation methods. For example, huge

differences between the hetero-evaluation conducted and all other evaluation types would reveal a lack of evaluative objectivity on behalf of students.

2. *Self-evaluation*. Students evaluate their own task performance in accordance with the provided rubric. This strives, amongst other things, to identify and rate individual learning in order to provide a basis from which performance can be judged and improved. It has been demonstrated that this process tends to have a huge impact on student learning (Martínez-Figueira et al., 2013). It is crucial to use the same rubric as that used in all other conducted evaluation to be able to avoid and quantify potential evaluation bias due to subjective factors pertaining to self-perceptions (Basurto-Mendoza et al., 2021).
3. *Co-evaluation*. Another individual or group of individuals rates the task performance of their peers with the evaluation process focusing on following criteria outlined for the applied rubric. This phase strengthens the development of

critical thinking for analysing and understanding the work performed by one's peers (Hanrahan & Isaacs, 2001). In addition, it promotes learning throughout the process of co-evaluation, representing a progression from individualised work and learning (Boud et al., 2009). According to Vivanco-Álvarez & Pinto-Vilca (2018), this type of approach also increases student motivation for self-learning, given that the evaluation of performance progresses from being a control tool to being a tool for gathering useful information.

This alternative evaluation model strives to promote participation, transparency, homogeneity and impartiality during the evaluation phase. The process ends by establishing a final rating that is weighted by the contributions of each of the phases discussed above. The present work proposes a specific evaluation methodology and survey, developed under the premise of competence-based evaluation and mixed learning (face-to-face, distance). The method was trialled in scientific-technological practical sessions and was based on the 360-degree method. This method was implemented in different Bachelor's and Master's degree courses belonging to the industrial knowledge branch and imparted through the School of Industrial Engineering at the University of Malaga. In this way, the present methodology aspired to stimulate the motivation of students participating in a phase of the educational process in which they are not traditionally permitted to engage. This is done through interactions with the teacher and all other students during determined stages of the evaluation processes in which the instruments and evaluation, correction and rating criteria are established.

Method

Purpose and objectives

Application of the 360-degree feedback methodology proposed in the present study sought to address a series of objectives from a didactic viewpoint and from a research

standpoint. The following didactic objectives were pursued:

- Perform an analysis of the influence of this methodology within different groups, such as degree level (Bachelor's or Master's), sex (male or female), and as a function of the evaluation system (gamification, recall of practical sessions and oral presentation), whilst, at the same time, finding a link between this and potential improvements in student participation in and motivation towards their learning process. Students are provided with the tools required to enable them to compare their performance with that of their peers, converting evaluation from a simple control tool into a tool for gathering useful information and, further, enabling a glimpse at the role of the evaluator (Vivanco-Álvarez & Pinto-Vilca, 2018, Boud et al., 2009; López-Cózar-Navarro et al., 2020).
- Conduct an analysis of quantitative responses regarding the weighting considered by students to be the fairest for evaluating practice. This enables the developed rubrics to be fully taken advantage of as a facilitator of learning (Blanco 2008; Etxabe et al., 2011; Martínez-Figueira et al., 2013).

On the other hand, from a more investigative and innovative point of view, the following objectives were also pursued:

- Validate the satisfaction with 360-degree feedback survey through a formal process (confirmatory factor analysis) for its potential frequent use in all other subjects pertaining to the industrial knowledge branch.
- Observe and quantitatively analyse identifiable discrepancies in the analysis of different groups, in addition to the interaction between the three agents (teacher evaluation, student self-perceptions and perceptions of other peers). Following this, improvements will be proposed to address identified shortcomings.

Although both types of objectives will be addressed in an isolated way, outcomes will ultimately provide responses to the overarching question pertaining to the degree to which the evaluation method examined in the present study is effective, both in terms of students in general and in terms of the groups outlined below.

Participants

The evaluation described above was conducted in modules delivered during the 2019/2020 and 2020/2021 academic years. All modules belonged to engineering Bachelor's or Master's degree courses and corresponded to different knowledge areas (electrical, robotics, fluids, mechanics, electronics, industrial manufacturing, applied physics). The course in which the evaluation was conducted is presented in Table 1, alongside the number of students enrolled on each course.

Table 1. Modules and number of students on the two degree courses (Bachelor's [n1,2,4,5 and 7] and Master's [n3 and 6]) in which 360-degree feedback evaluation was conducted.

N	Module	Course	N participants/Total number of students
#1	Numerical simulation of the flow around vehicles	Master's 1	7/8
#2	Fluid movement around vehicles	Master's 1	3/4
#3	Teleoperation and telerobotics	Master's 1	2/4
#4	Physics I	Bachelor's 1	63/64
#5	Photovoltaic instillations	Bachelor's 4	15/20
#6	Fault-tolerant mechatronic systems	Master's 1	3/4
#7	Industrial processes	Bachelor's 3	60/63
			TOTAL: 153/167

Sample distribution is presented in Table 2. Participants made up a sample comprising a total of 153 datapoints. It can be seen that sample distribution according to sex and degree course corresponds to that expected within the population, with approximately

30% being female compared with 70% male and a ratio of nine Bachelor's students for every Master's student (both statistics are practically identical to those published by the Ministry of Universities (2019) for the 2019/2020 academic year).

Table 2. Sample characteristics.

Sex	Male	70.45 %
	Female	29.55 %
Degree	Bachelor's	90.2 %
	Master's	9.8 %
Module	Physics I	41.2 %
	Industrial processes	39.22 %
	Photovoltaic instillations	9.8 %
	Numerical simulation of flow around vehicles	4.57 %
	Fault-tolerant mechatronic systems	1.96 %
	Fluid movement around vehicles	1.96%
	Teleoperation and telerobotics	1.31 %

Questionnaire design

The questionnaire comprises a series of questions with the aim of addressing different groups of issues that are sufficiently representative of all of the possible dimensions to be expected in a study of satisfaction. In other words, the questionnaire aimed to evaluate diverse aspects related with student adaptation (Baker & Siryk, 1984), motivation (Tuan et al., 2005), satisfaction (Douglas et al., 2006) and acquisition of skills/learning (Alarcon et al., 2017). The survey differentiated different blocks of potential issues, in the same way as that described by Santos-Pastor et al. (2020). Considering that the purpose of the present work is to examine the effectiveness of the survey for gaging student satisfaction with the 360-degree method in the context of industrial modules, it was decided to create blocks or dimensions that contained different responses to questions of interest for this type of examination. The main aim of this was to understand the extent of individual satisfaction and benefit associated with this novel approach. This line of questioning involving individual appraisal is found in many questionnaires (Santos-Pastor et al., 2020; Casero-Martínez, 2008) and enables student satisfaction to be accurately measured. A search for a battery of questions of this nature informed the development of a block of questions oriented towards the quality of training posed within the individual self-evaluation group (*1-Personal evaluation*). On the other hand, given the evaluation method used, it was important to identify student perceptions of the requisites underlying the evaluation method. Such questions are of vital importance because ratings are irrelevant to those being rated when they are based on unfair criteria. Casero-Martínez (2008) has previously urged caution in this regard, arguing that impartiality in evaluations is crucial to students, as is having the opportunity to intervene to correct rubrics (in cases in which requisites are not met, the intention behind the intervention is important). Thus, questions to canvass opinions about evaluation

criteria are repeated throughout evaluation questionnaires (González López & López Cámara, 2010), with the questionnaire used in the present study grouping such questions within a specific block (*2-Criteria*). Likewise, students may feel a lack of subjective affinity between themselves and teaching staff. This, in some way, may be reflected through heterogenous evaluations. All questions related with objectivity are grouped into dimension *3-Evaluation objectivity*. Given that it is also important to know whether, as a result of this experience, students improved their understanding about the way in which an evaluation system operates and developed more critical and responsible attitudes, whilst also gaging the impact of the evaluation on the teaching-learning process, the dimension, *4-Learning experience*, was conceived, in accordance with the recommendations of Basurto-Mendoza et al., (2021). Finally, a fifth battery of questions was posed that comprised categorical questions pertaining to the weighting considered by students to be most appropriate (*5-Weighting of evaluations*). Responses to these questions are useful to be able to appreciate the weight given by students to each evaluation and, from this, make overall conclusions in light of the “rigid” responses given to the previously posed questions.

Evaluation methods used in 360-degree feedback analysis

Each module possesses some inherent characteristics that mean that the chosen evaluation method is one that maximises evaluation fairness. In total, three different methods were used:

- **Practical laboratory session reports.** After students hand-in their report on practical sessions, the report is initially evaluated by a peer (co-evaluation) and, subsequently, the student themselves conducts a self-evaluation of their own work. Weightings given to calculate a final grade were: 50% hetero-evaluation, 30% co-evaluation and 20% self-

evaluation. The modules in which this methodology was applied were modules #1, #2, #4 and #5 (see Table 1).

- **Gamification.** The only module in which this methodology was used was #7 (Industrial Processes). This module contains different theoretical material that must be studied and understood, meaning that it is very difficult for students to cover everything in such a short time period prior to practical sessions. Games or gamification incentivises engagement by getting students to have blocks of questions ready prior to practical sessions.

It generates a competitive environment between teams who launch questions at one another (it is also possible to generate a large number of sub-divisions given the large number of students typically engaged in these modules). This competition is real as a grade is assigned according to the order of students at the end of the final semester. This method has previously been heralded by authors such as Orji *et al.* (2017), due to its complete success regarding the number of students achieving a passing grade for practical sessions and final reported grades.

Table 3. Dimensions and items (questions) included in the 360-degree feedback survey.

Group or dimension	Item n	Item wording
Personal evaluation	Q01	Has participation in the evaluation experience helped you to understand course material?
	Q02	Has participation in this experience helped you to detect conceptual failings in course content?
	Q03	Has participation in this experience helped you to be more responsible and take more of a leading role in your own learning?
	Q04	Has participation in this experience helped you to improve your learning approach?
	Q05	Does knowing that you are going to evaluate each other provide you with an “extra” motivational push to perform the activity?
Criteria	Q06	Were the documents provided by teachers to conduct the evaluation intuitive and easy to interpret?
	Q07	Do you think that the evaluation criteria are suitable?
	Q08	Do you think that the scoring for the sections under evaluation are suitable?
	Q09	Rate the documents provided by teaching staff to conduct the evaluation (rubric, evaluation criteria, scoring and correction, etc.).
Evaluation objectivity	Q10	Was the self-evaluation you performed objective and fair?
	Q11	If you do not know, respond 0: Was the co-evaluation you received from your peer’s objective and fair?
	Q12	Did you perform a fair and objective co-evaluation of your peers?
	Q13	Do you believe that ensuring anonymity is an important factor regarding co-evaluations between students?
	Q14	Can you guarantee that knowing or maintaining a friendship with those being evaluated did not influence the co-evaluations carried out (positively or negatively)?
Learning from the experience	Q15	Was the evaluation performed by your teachers objective and fair?
	Q16	Did participation in this experience enable you to better understanding the evaluative role of teaching staff?
	Q17	Do you consider that you learned more through this experience than through traditional methods?
	Q18	Do you think it would be interesting to apply this experience to other modules?
	Q19	Would you recommend the module you study based on your experience of the evaluation carried out?
	Q20	Objectively, what rating would you give to this experience?
Evaluation weightings	Q21	What type of weighting do you think would be reasonable to give to the self-evaluation?
	Q22	What type of weighting do you think would be reasonable to give to the co-evaluation?

Q23

What type of weighting do you think would be reasonable to give to the teacher evaluation?

- **Presentation of work.** This concerns performing a written report to present later in an oral presentation. The three evaluations comprising 360-degree feedback are constructed as 70% design and implementation, 15% presentation and 15% discussion. The modules in which this methodology was applied were #3 and #6.

Results and Discussion

The sample used to test the 360-feedback methodology was made up of four overarching groups pertaining to evaluation modality (gamification, written assignment, oral presentation), sex (male or female), degree (Bachelor's or Master's) and academic year (1st year module vs 3rd year module). Confirmatory factor analysis was conducted to evaluate the structure of the proposed dimensions and rate survey outcomes. Following this, the groups described above were analysed in order to extract data as a function of groups. In addition to analysing survey responses via a Likert scale, an analysis of the fairness of weighting in the view of students was conducted (to enable identification of the type of weighting applied to the hetero-auto-co-evaluation shortlist considered by students to be fairest in according with their own criteria).

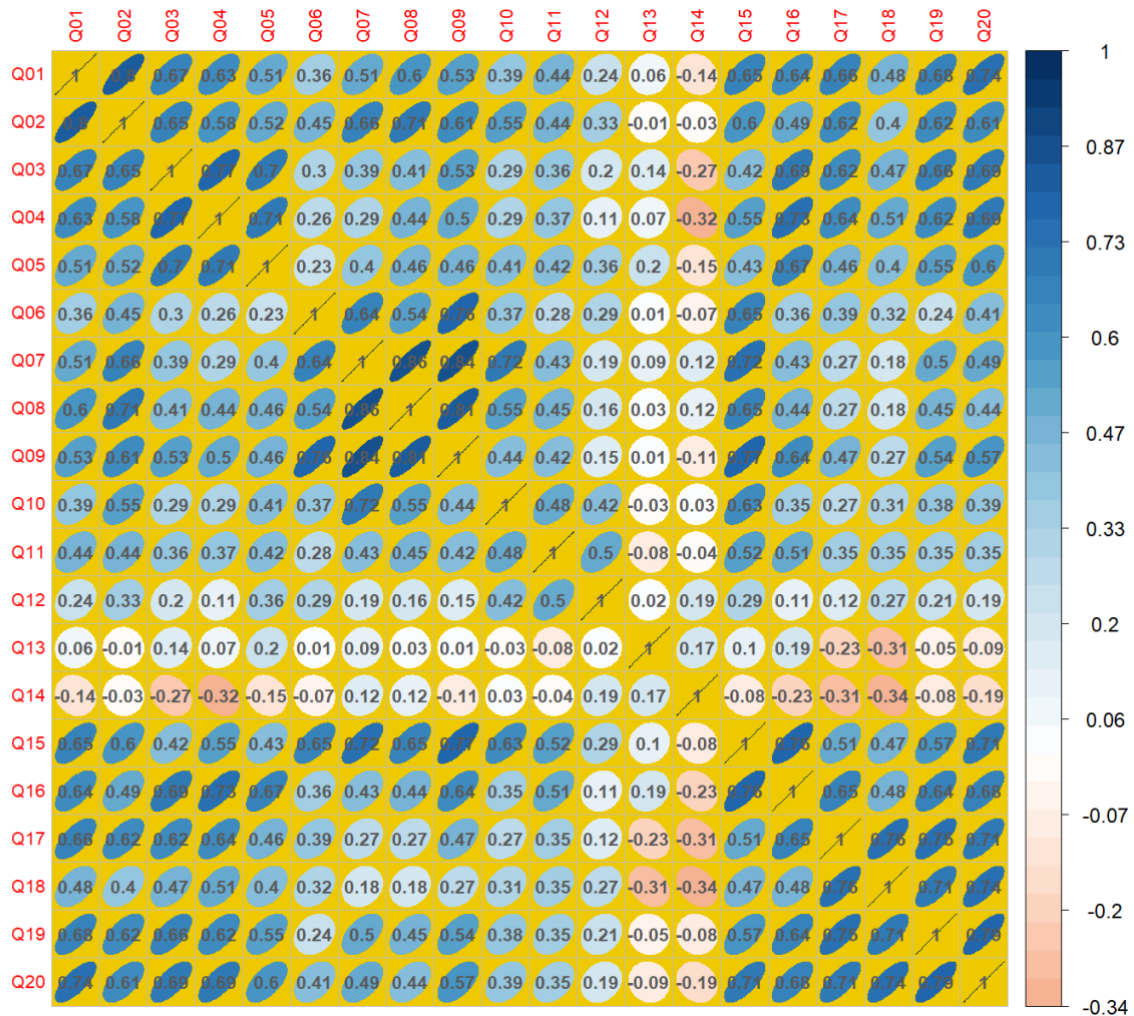
Confirmatory factor analysis

Confirmatory factor analysis was conducted to analyse the structure of dimensions or groups pertaining to the blocks of questions or items responded to along a Likert scale (Likert 1932, Albaum, 1997). For each questionnaire item, those surveyed indicated the extent to which they agreed or disagreed with a statement put to them. The typical five-option response format used was as follows: TD=Totally disagree, D=Disagree, N=Neutral, A=Agree and TA=Totally agree. As laid out in Table 3, survey structure comprised four clearly differentiated groups.

In contrast to all the other questions that were responded to along a typical Likert scale, question Q11 (*Was the co-evaluation you received from your peers objective and fair?*) gave students the option to respond that they did not know. Such a response would fall outside of the format of the five-level Likert scale established for all other questionnaire responses. In this case, responses were coded as 0 NS/NC to denote lack of information and the truncated mean was imputed for survey analysis. This was appropriate given that the probability distribution of responses hardly changed.

One way to determine whether a given question disrupts the distribution of survey responses is to conduct an analysis of the correlations between different question responses. For this reason, prior to confirmatory factor analysis, the correlation matrix was calculated. Given that variables were categorical and ordinal in nature (Likert scale responses range from lower to higher degree of agreement), polychoric correlations provided the most appropriate relational outcomes (Jöreskog 1994). Figure 2 reveals the correlation matrix. It can be observed from this figure that the correlation between all variables (items or questions) was positive, with the only exception being for questions Q13 and Q14, with these being associated with a negative correlation. These correlations are shaded in within the figure. These two questions address anonymity. Indeed, Q13 (*... anonymity is an important factor regarding co-evaluations between students?*) and Q14 (*...maintaining a friendship with those being evaluated did not have an impact on co-evaluation...*) were opening questions to which insincere responses could be expected, given that it is to be expected that knowing, personally, the peer involved may influence the way in which they conduct an evaluation (Gong, 2016). Thus, these two questions do not have the same reliability as the other items and must be discarded.

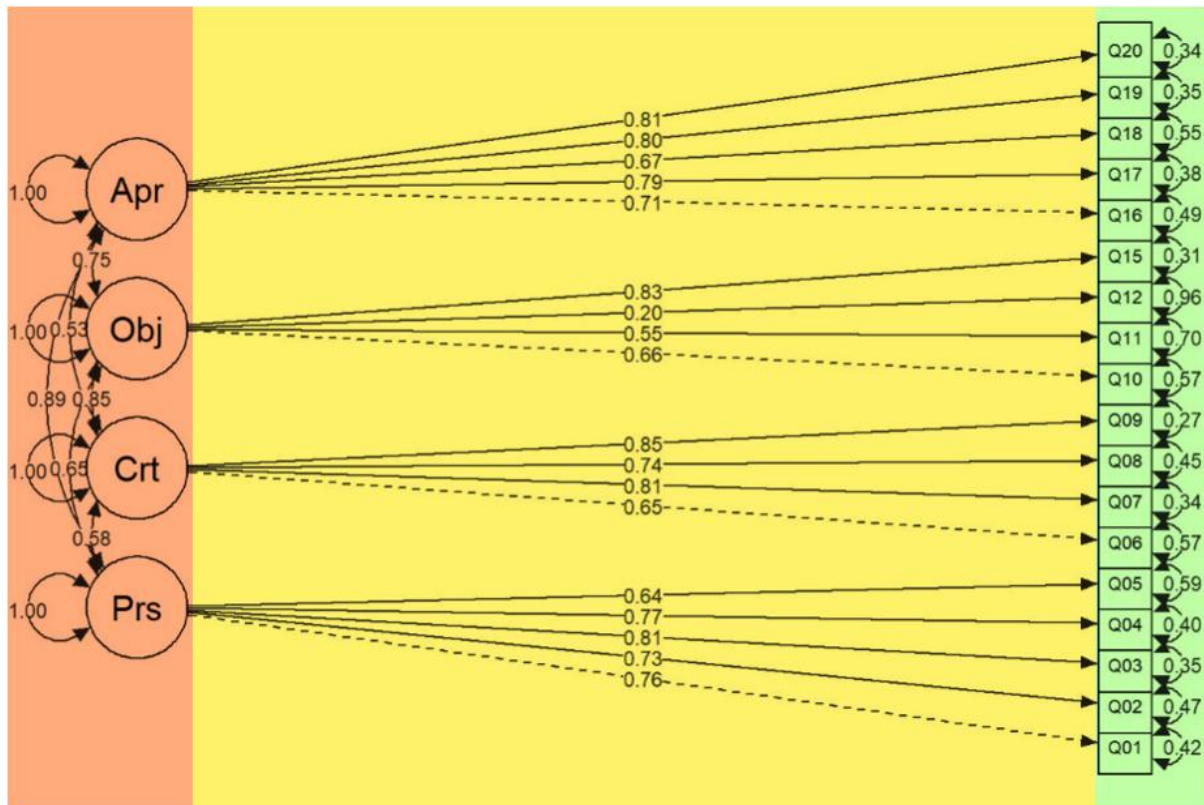
Figure 2. Polychoric correlation matrix.



Finally, the model produced from confirmatory factor analysis is shown in Figure 3. The four examined dimensions (also denominated latent variables or constructs) are represented via circles and are shown highlighted in orange: *Personal evaluation* (Prs), *Criteria* (Crt), *Evaluation objectivity* (Obj) and *Learning from the experience* (Lrn). The squares highlighted in green designate the questions posed (item or observed variable) by

the survey. The arrows joining latent and observed variables, appearing in the figure highlighted in yellow, reflect multivariable model weights. Two-way arrows around the circular elements highlighted in orange (dimensions) indicate the covariance pertaining to these aforementioned dimensions. Two-way arrows around the square elements highlighted in green (observed variables) indicate residual variances.

Figure 3. Confirmatory factor analysis model.



Model goodness of fit was analysed through the famous chi-squared test ($\chi^2 = 288.554, df = 129, pval = 0.0$), with df being degrees of freedom and $pval$ being the p-value (García Cueto et al., 1998), with the significance level typically being set at $pval = 0.05$. With regards to root mean square error of approximation (RMSEA) and standardised root mean squared residual (SRMR), as absolute indices, $RMSEA = 0.1$ was obtained. This indicates that the model is well-fitted to the data (González-Montesinos & Backhoff, 2010). Further, SRMR analysis produced a value of 0.08, with this indicating reasonable fit (Rojas-Torres, 2020). As relative indicators, comparative fit (CFI) and Tucker-Lewis (TLI) indices were calculated. Outcomes also revealed an acceptable fit of the model to the data with acceptably high values being produced ($CFI = 0.83$ and $TLI = 0.8$).

Internal consistency

Internal consistency of the survey was analysed based on the Cronbach alpha (α). Use of this parameter as a measure of the internal consistency of the survey is justified based on the fact that, as shown by existing literature (Rodríguez-Rodríguez & Reguant-Álvarez, 2020), this parameter measures covariance between different survey questions. In this regard, greater covariance means higher Cronbach alphas. An outcome of $\alpha = 0.919$ was obtained, with this value denoting a high degree of reliability (Cronbach, 1951, Nunnally, 1978). Likewise, Guttman's λ_6 was calculated, producing $\lambda_6 = 0.952$. λ_6 is another measure of consistency that is largely similar to α , but more sensitive to the number of scale elements. These measures of consistency make it possible to establish the extent to which surveyed individuals can be differentiated based on the veracity of their responses, with such estimations being based on variance. High values for these parameters

indicate that the large majority of responses can be considered to be true. This is a highly useful tool for detecting questionnaire responses of dubious quality (a student may respond to the questionnaire quickly and randomly). Values for both of these parameters are considered to be very good when they are higher than 0.9. Table 4 presents outcomes of the reliability analysis conducted for all items, alongside element-scale, r , correlations. From the outcomes presented in the table, it can be observed that the exclusion of each item fails to have a meaningful impact on overall consistency of the survey. The only item of questionable relevance is Q12 (corresponding to perceptions about whether the respondent has conducted a fair and objective co-evaluation of their peers). This presents a fairly

weak correlation, possibly due to the fact that respondents are presented with a conflict of interest with regards to the way in which they see their peers. It was decided not to eliminate this item as it is of huge informational importance to the survey. A relatively low correlation was also produced for question Q06 (regarding whether the documents provided by teaching staff to perform the evaluation are intuitive and easy to interpret) in comparison with the previous questions. This was possibly due to the fact that student responses were, once again, influenced by a conflict of interests, although, in this case, considerably fewer doubts are likely given that it tends to be easier for students responding anonymously to a survey to express criticism towards teaching staff than it is to do so towards their peers.

Table 4. Reliability indices when each item is eliminated and element-scale correlations

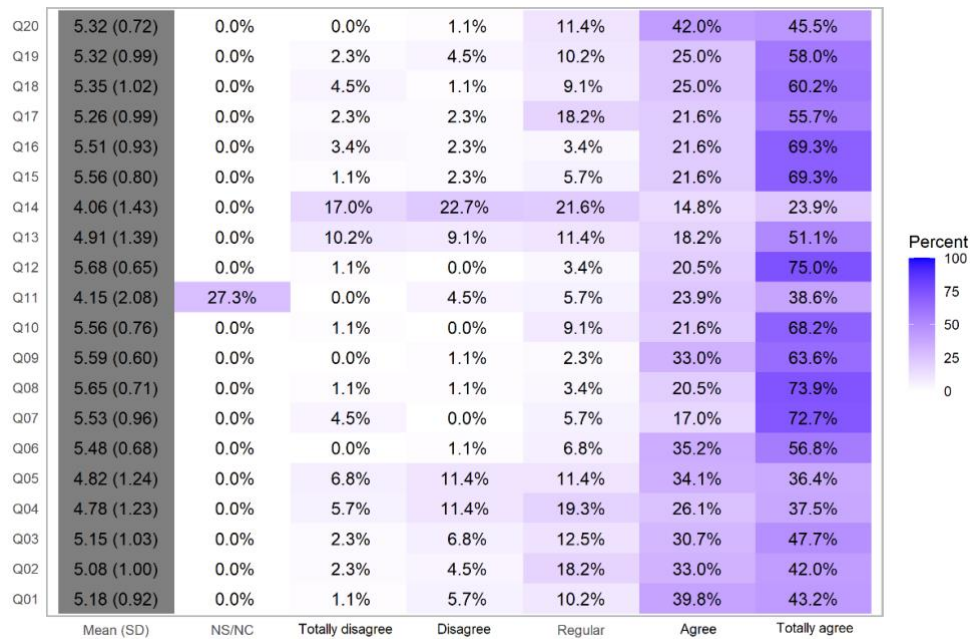
Item	r	α following item elimination	λ_6 following item elimination
Q01	0.757	0.911	0.947
Q02	0.761	0.911	0.947
Q03	0.730	0.912	0.948
Q04	0.718	0.913	0.948
Q05	0.655	0.916	0.949
Q06	0.486	0.918	0.950
Q07	0.573	0.917	0.946
Q08	0.598	0.916	0.949
Q09	0.682	0.914	0.947
Q10	0.603	0.916	0.949
Q11	0.579	0.916	0.951
Q12	0.272	0.922	0.954
Q15	0.716	0.913	0.945
Q16	0.729	0.912	0.945
Q17	0.721	0.912	0.947
Q18	0.604	0.916	0.950
Q19	0.757	0.911	0.947
Q20	0.774	0.912	0.946

Generic analysis of the sample

Firstly, distribution of scale response was analysed. Figure 4 presents a heatmap of the distribution of responses. As mentioned above, question Q11 is the only item to possess the

NS/NC response option, just as gathered by the original survey (also keep in mind that the mean distribution of these values was imputed in CFA to not disturb the structure of the distribution).

Figure 4. Heatmap of the distribution of survey responses regarding 360 feedback



From the analysis of questionnaire responses it can be seen, generally speaking, that students were highly satisfied with the 360-degree feedback. Responses to questions pertaining to the personal evaluation block: Q01 (...understanding of content...); Q02 (...detect conceptual shortcomings...); Q03 (... take a leading role in my own learning...); Q04 (...improve my approach to studying...) and Q05 (...“extra” motivation...) showed a very high level of agreement (the sum of A [agreement] and TA [totally agree] responses), with TA emerging slightly above A. Nonetheless, questions from the criteria block: Q06 (...documents provided by teaching staff for evaluation...); Q07 (...evaluation criteria are suitable...); Q08(... scoring of the sections...) and Q09 (...rating of documents provided by teaching staff...) also produced a large number of TA responses. This reveals a very high degree of satisfaction in the criteria provided for 360-degree feedback. The evaluation objectivity block also produced very high levels of agreement (the sum of A and TA), with the number of TA responses standing out. This being said, question Q13 (... anonymity of co-evaluation ...) produced a number of responses indicating disagreement. This reveals that a notable percentage of

students stated that knowing the identity of those being evaluated influenced them with regards to their co-evaluation. This finding agrees with Gong (2016), who suggested that “when conducting peer evaluation, it is inevitable that one will be influenced by human feelings” and considered confidentiality to be a necessity. Comparable to this first block, a high degree of satisfaction was also shown in response to the block of questions addressing learning from the experience, with an even greater percentage of respondents reporting that they totally agreed. This supports the conclusion that students are open to using this new method and that they positively rate the performance of teachers compared with traditional evaluation methodologies. This has also been highlighted by other authors (Sotelo & Arévalo, 2015). Further, Vivanco-Álvarez & Pinto-Vilca (2018) identified peer evaluation as a hugely important tool for quantifying the motivation of students undertaking humanities degrees. The same finding appears to emerge with regards to engineering degrees, as shown by the present study. The finding that only 37.5% of students considered the experience to be highly favourable, 26.1% reported it to be favourable and 19.3% reported an average

impact on their study approach (Q04). This highlights the importance of teachers for improving aspects related with the study method and decreasing dropout rates (García et al., 2016). Turning attention to student responses to questions Q01, Q02, Q03 and Q04, in all cases, less than 50% of students reported that they totally agreed. As all items are directly related with the teaching-learning process, it serves to highlight the importance to students of the search for innovation resources in the classroom, as these improve the study capacity of students. This finding may point to an important line of future research. An example of a potential improvement could be to set up online work groups to provide training on the topic of study in the evaluation under the tutelage of teaching staff. In this way, students would benefit more from this methodology, stay in close contact with teachers and reinforce their capacity for self-directed learning, upskilling and motivation (García et al., 2016). Unfortunately, conclusions cannot be drawn from the present survey regarding the best way to improve academic performance through the experience described. Nonetheless, given the high degree of satisfaction observed and experience with similar evaluation strategies reported in the literature (Basurto-Mendoza et al., 2021; Vivanco-Álvarez & Pinto-Vilca, 2018; Sotelo & Arevalo, 2015), it is to be expected that transversal implementation of the present methodology may increase student performance, achieving reduced dropout rates and, even, attracting a higher number of enrolments, with these representing particularly big challenges in engineering at presents.

Analysis of the sample as a function of groups

Data reported by the sample was also analysed as a function of the following groups: first-year/advanced modules (1st or 3rd year of the degree), sex (male or female), evaluation modality (report on practical sessions, gamification and oral presentation) and degree type (Bachelor's or Master's).

Analysis as a function of module

For this analysis, responses given regarding 360-degree feedback in two modules with a similar number of students (around 60 in each module) were analysed. Physics is taught in the first trimester of the first year, at the beginning of the degree. Students studying this material have recently enrolled at the university and have a profile that is more characteristic of a secondary school student than a university student. On the other hand, students undertaking Industrial Processes, a module imparted during the third year of the degree, already have a number of years of university experience. This clear difference in the profiles of students undertaking the examined modules awakens interest in conducting a comparative analysis of the questionnaire responses given by both student groups in order to evaluate whether student training throughout the degree contributes towards promoting academic maturity. Yani et al. (2019) consider that academic maturity is reached when student perceptions are more closely aligned to academic reality. Toppin (2016) suggests that academic maturity emerges alongside critical thinking. Although both topics are challenging to evaluate, a complete interpretation of questionnaire outcomes could shed light on the evolution of the university experience of students over the course of their degree. In this way, for example, questions relating to the personal evaluations of students (Q01-Q05) provide an idea of the outcomes students expect to achieve from a given module. Thus, this block of questions could be related to student academic maturity. On the other hand, questionnaire questions pertaining to *criteria*, *evaluation objectivity* and *learning from the experience* se could be related with an evolution towards more critical thinking in students.

With regards to the response block corresponding to students' personal evaluations (questions Q01 to Q05), both groups were found to be optimistic, as shown in Figure 5. Nonetheless, generally speaking, first-year students were more optimistic than third-year students. In this sense, 81% of first-year students were in agreement (A) or totally

agreed (MA) relative to 75% of third-year students when responding to question Q02 (... detect conceptual shortcomings...). 62% of first-year students, compared with 50% of third-year students, reported agreeing or totally agreeing with question Q04 (...improve approach to studying...), whilst 76% of first-year students and just 69% of third-year students responded A or TA to the item describing receiving “extra” motivation from self-evaluation (Q05). 75% of third-year students reported agreement or total agreement that the evaluation system had helped them gain better understanding of module content (Q01) compared with 80% of first-year students. Further, 69% of third-year students, compared with 76% of first-year students, trusted that the present evaluation process would lead to them having more responsibility over their own teaching-learning process (Q03). After comparing the responses given by students on both modules, it could be concluded that first-year students were more optimistic, whilst third-year students were more realistic, with regards to their expectations for academic outcomes. This indicates a higher degree of academic maturity in third-year students, in line with that discussed by Yani et al. (2019).

With regards to evaluation criteria, 83% of first-year students and 88% of third-year students were in agreement (A) or total agreement (TA) that the documents provided by teachers to carry out self- and co-evaluations had been clear (Q06). 94% of first-year students and 97% of third-year students positively rated the documentation provided by teachers (Q09). Although the majority of students from both groups were in agreement or total agreement that the documentation provided by teachers and evaluation criteria established were suitable, a higher number of third-year students were found to be behind the 360-degree feedback approach. This could be interpreted as a positive appraisal of the university experience lived by these students. 88% of first-year students and 85% of third-year students highly or very highly rated the evaluation criteria set by the teacher (Q07),

with 65% being in total agreement. 90% of both groups provided positive responses to the question Q08 (... rating of the scoring used for the sections under evaluation...), although 78% of third-year students compared with 72% of first-years students were in total agreement with scoring criteria. Despite there being little difference in the distribution of responses, third-year students were more aware of the academic implications of conducting an interactive evaluation. This awareness could be interpreted as a positive evolution towards academic maturity.

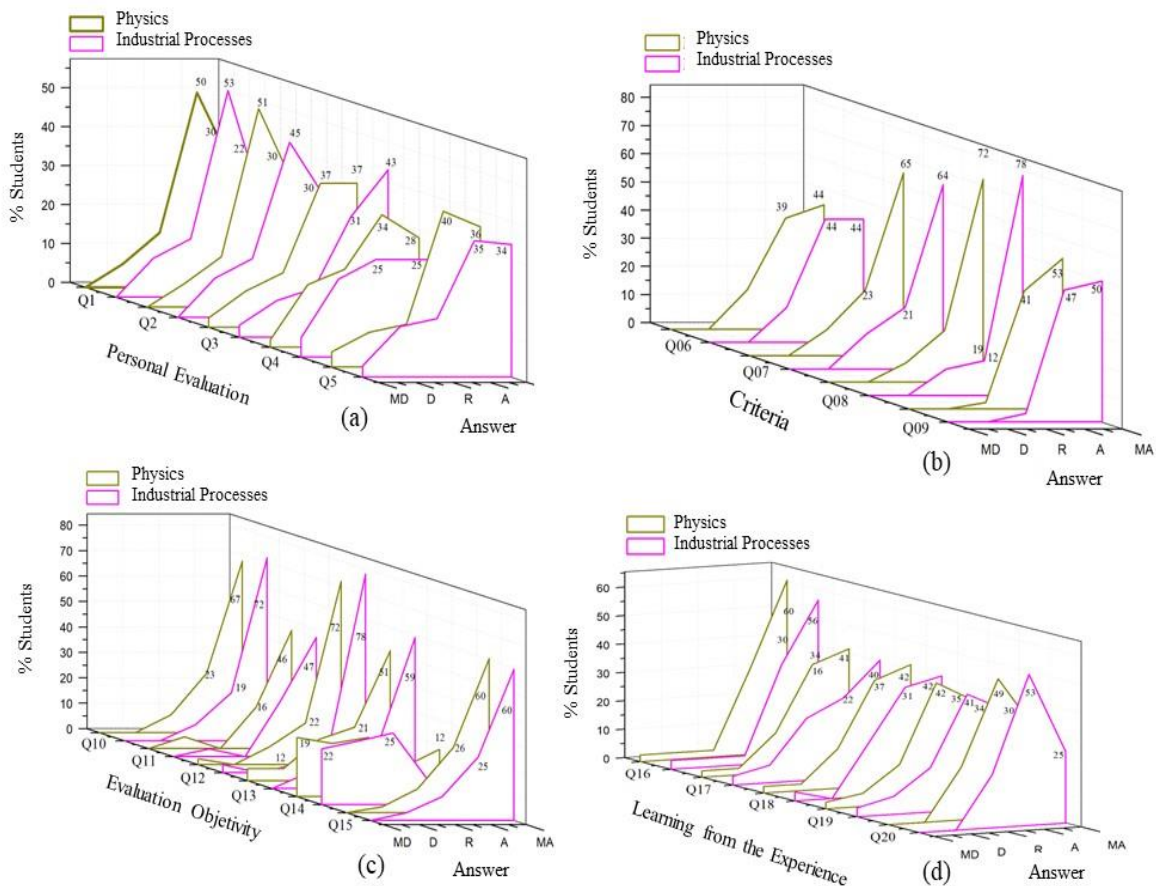
Evaluation objectivity (Q10) was positively scored by 90% of first-year students and 91% of third-year students, see Figure 6. Objectivity of the co-evaluation process (Q11) was less positively rated by both groups, with 62% and 69% of first- and third-year students, respectively, being in agreement or in total agreement. The degree of objectivity in 360 feedback with peers (Q12) was highly rated, specifically, by 88% of first-years students and 90% of third-year students. Nonetheless, the two groups considered that friendship might have influenced their co-evaluation (Q14), with 31% of first-year students and 25% of third-year students stating that their peers' friendship had not had an impact. Although response distribution was similar in both groups, a positive evolution was detected in the critical nature of third-year university students. This outcome could be interpreted as a trait of academic maturity. In this sense, third-year students were more likely to agree that anonymity of the evaluation was preserved (Q13), with 78% agreeing relative to 72% of first-year students. This points to a more realistic view of evaluation objectivity within third-year students. With regards to the teacher evaluation, the percentage of positive responses was similar in both groups, specifically, 86% and 85% in first- and third-year students, respectively.

In the case of the learning taken away from the experience, 91% of first-year students considered that the present evaluation method was useful for improving knowledge of course material (Q16), relative to 90 % in third-year

students. 78 % of first-year students and 79 % of third-year students highly or very highly rated the experience (Q20). With regards to question Q17 (...learning compared with traditional methods...), Q18 (...application of the experience to other modules...) and Q19 (... would recommend the module based on the evaluation method employed...), responses from both groups were fairly similar. Approximately 80% of students from both

groups highly or very highly rated these items. In summary, as previously discussed when presented the generic analysis, students from both groups highly positively rated the experience. Nonetheless, more realistic and critical perceptions of the 360-degree feedback process were observed in third-year students, indicating greater academic maturity and more veteran students

Figure 5. Distribution of responses to the 360-degree feedback survey, according to module. Numerical values are presented for students who reported agreement or total agreement. Responses are grouped as a) Q01 to Q05, b) Q06 to Q09, c) Q10 to Q15 and d) Q16 to Q20.



Analysis as a function of sex

Outcomes from this comparative analysis are presented in Figure 6. With regards to sex-based analysis, response distribution was, generally, highly similar, although some nuanced outcomes will now be discussed below. In the case of the first three questions from the *personal evaluation* Q01

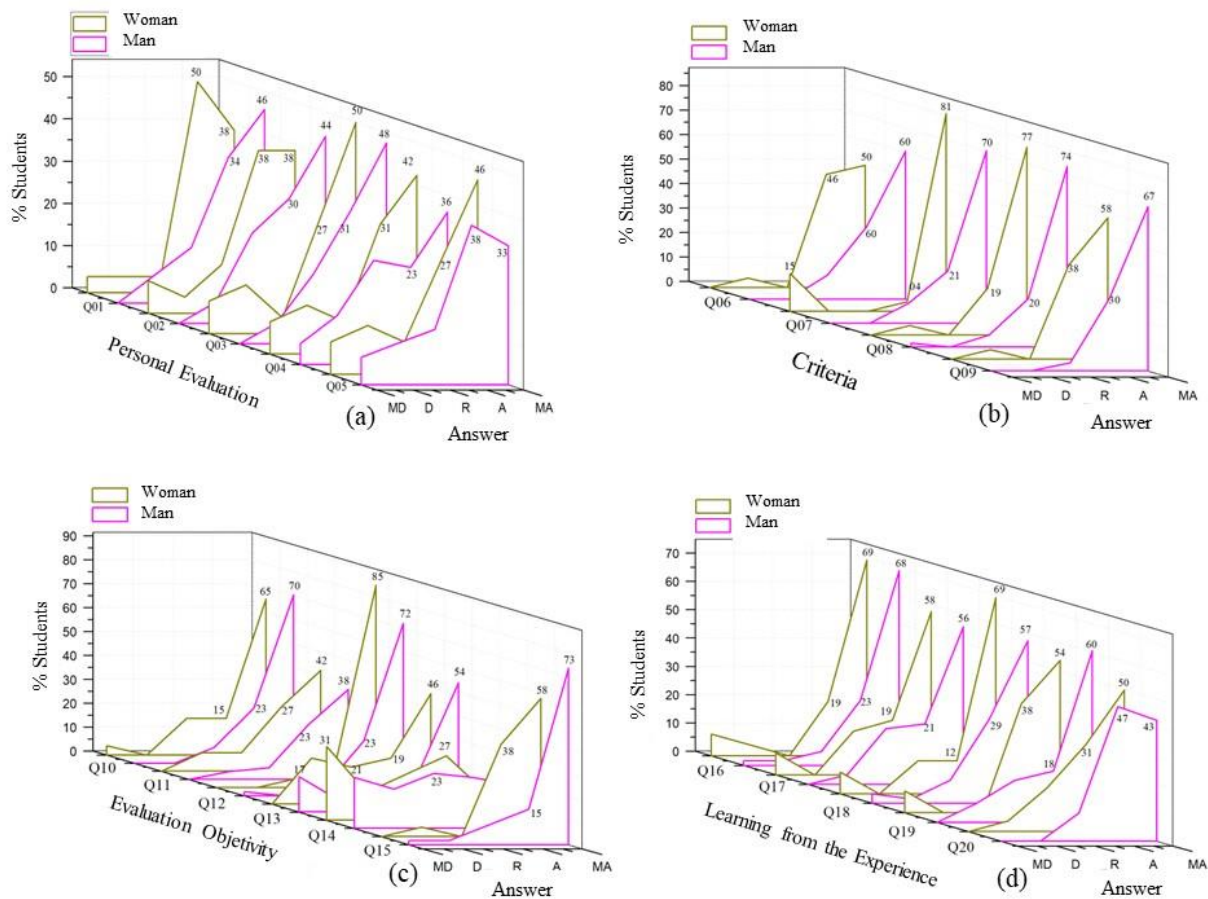
(...understand module content...), Q02 (...detect conceptual shortcomings...) and Q03 (...be more responsible and take a leading role in my own learning...), a slightly higher proportion of males than females provided positive responses. Responses to question Q04 (...improve my approach to studying...) were similar regardless of sex

(81% of females and 82% of males). The reason behind these results, tentatively speaking, could be linked to expectations regarding academic results. In this sense, females are more realistic than males, as their expectations tend to be grounded in previous experiences (Rodríguez et al., 2015).

Males are somewhat more positive than females with regards to criteria (items Q06-

Q09) and participation and learning from the experience (items Q16-Q20). Females were more positive with regards to evaluation objectivity (items Q10-Q15). These outcomes may be explained by the slightly greater sense of responsibility and fairness found in women, as a result, potentially, of cultural context (Rodríguez et al., 2015).

Figure 6. Distribution of responses to the 360-degree feedback survey, according to sex. Numerical values are presented for students who reported agreement or total agreement. Responses are grouped as a) Q01 to Q05, b) Q06 to Q09, c) Q10 to Q15 and d) Q16 to Q20.

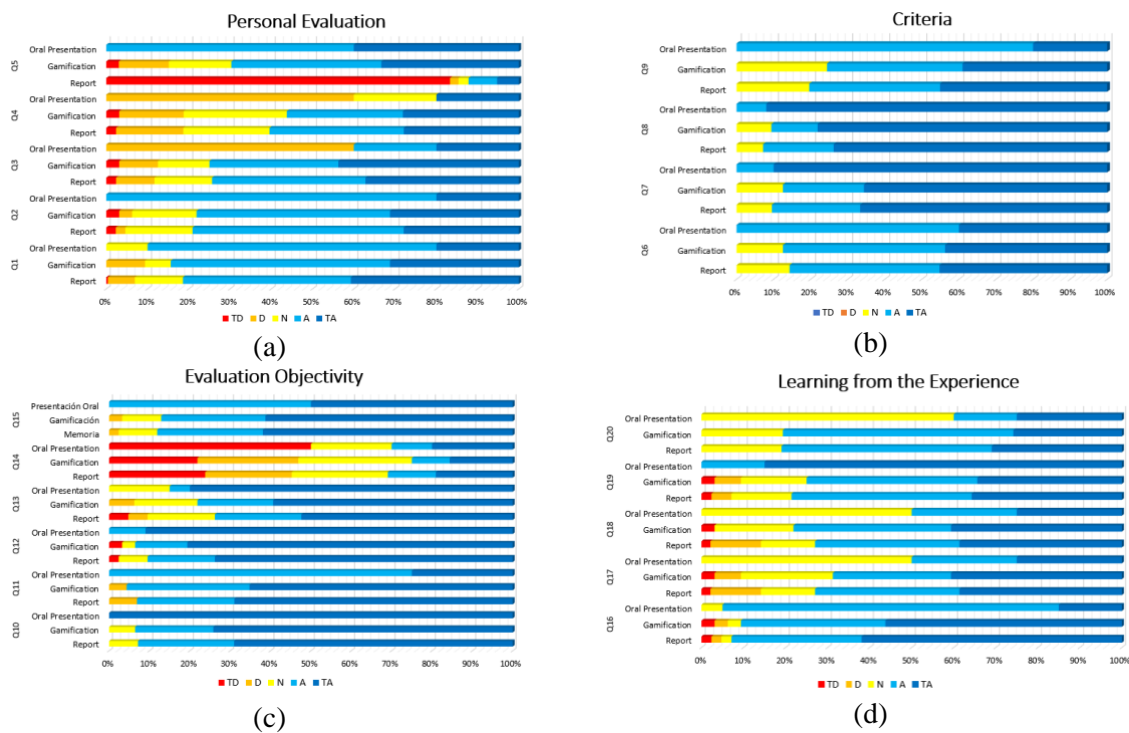


Analysis as a function of evaluation modality

For comparative analysis of this grouping, the hand-in of a written report of practical sessions was carried out in modules #1, #2, #4 and #5 (see numbering in Table 1),

gamification was conducted in module #7 and oral presentations were performed in modules #3 and #6. Survey outcomes corresponding to the sections of *personal evaluation*, *criteria*, *evaluation objectivity* and *learning from the experience* are presented in Figure 7.

Figure 7. Distribution of 360-degree feedback survey responses, according to modality: report, gamification or oral presentation. Responses are grouped as a) Q01 to Q05, b) Q06 to Q10, c) Q11 to Q15 and d) Q16 to Q20.



This figure gathers together responses comparing the three previously mentioned modalities. In the *personal evaluation* block, responses to the first question Q01 (... *understanding of content*...) clearly show that the majority of students (94%) who presented work in the form of an oral presentation reported a good or very good assimilation of course material, with this percentage being higher than in the other two modalities (written report and gamification). With regards to questions Q02 and Q04, related with the detection of conceptual shortcomings (Q02), responsibility over one's own learning (Q03) and improvement in the approach to studying (Q04), it serves to highlight that greater concordance existed between the responses given by students completing a written report or engaging in gamification, compared with those who performed an oral presentation. As indicated in Figure 7, 75-90% of students who were evaluated following the hand-in of a written report on practical sessions or through gamification were in agreement or total

agreement with the items presented in sections Q02-Q04. On the other hand, 100% of students who presented work via an oral presentation very positively rated question Q02, whilst questions Q03 and Q04 were rated highly positively by 40% and only 20% of students, respectively. Considering the fact that students in the oral presentation modality were Master's students, outcomes from questions Q02-Q04 could be interpreted as the consequence of more specialised learning, whilst, at the same time, representing a sign of academic maturity. Nonetheless, 100% of students who were evaluated via oral presentation considered self-evaluation to have given them an extra motivational push due to the 360-degree feedback approach. Questionnaire items related with evaluation criteria and the documentation provided by teachers (Q06-Q09) produced, generally, fairly positive ratings, particularly from students performing oral presentations, with 100% of these students positively rating these items. This finding may be explained by the fact that the students

involved received more specialised training provision, had more university experience, were used to oral presentations and were capable of distinguishing better interactive evaluation systems. Again, approximately 80% of students who presented work in the form of a written report or through gamification rated highly or very highly the evaluation criteria employed and the documents provided. It serves to highlight, that not a single student from any of the examined presentation modalities disagreed or totally disagreed with the evaluation criteria established by teaching staff.

Responses to questions related with evaluation objectivity showed a similar trend to that discussed above in relation to criteria. Approximately 85% of students who were evaluated via a written report or gamification considered self-evaluation (Q10), co-evaluation (Q11 and Q12) and teacher evaluation (Q15) to be fair and objective, whilst 100% of students evaluated via oral presentation positively rated these items. Nonetheless, questions related with anonymity (Q13) and friendship with those being evaluated (Q14) produced different ratings. Students who handed in a written report less positively rated anonymity (75%) compared with students evaluated through gamification (80%) and oral presentations (86%). In all cases, around 30% of respondents reported losing a degree of objectivity when evaluating peers with whom they had a friendship. Nonetheless, 50% of students who gave an oral presentation expressed agreement that friendship caused them to lose objectivity. It is evident that the teaching activity described here also has some disadvantages. Gong (2016) argues that confidentiality is essential and proposes that peer-review methods are intertwined with mutual learning processes and general improvements. It also creates a need to equip students to be able to evaluate other students. As can be seen in Figure 7, it is noteworthy that questions producing a wider spread of responses pertain to anonymity in evaluation (questions Q13 and Q14). With regards to question Q13, regarding whether

anonymity is an important factor in co-evaluation between students, students evaluated virtually and anonymously (written report on practical sessions) provided more positive responses than those evaluated in a non-anonymous way.

Analysis as a function of degree level

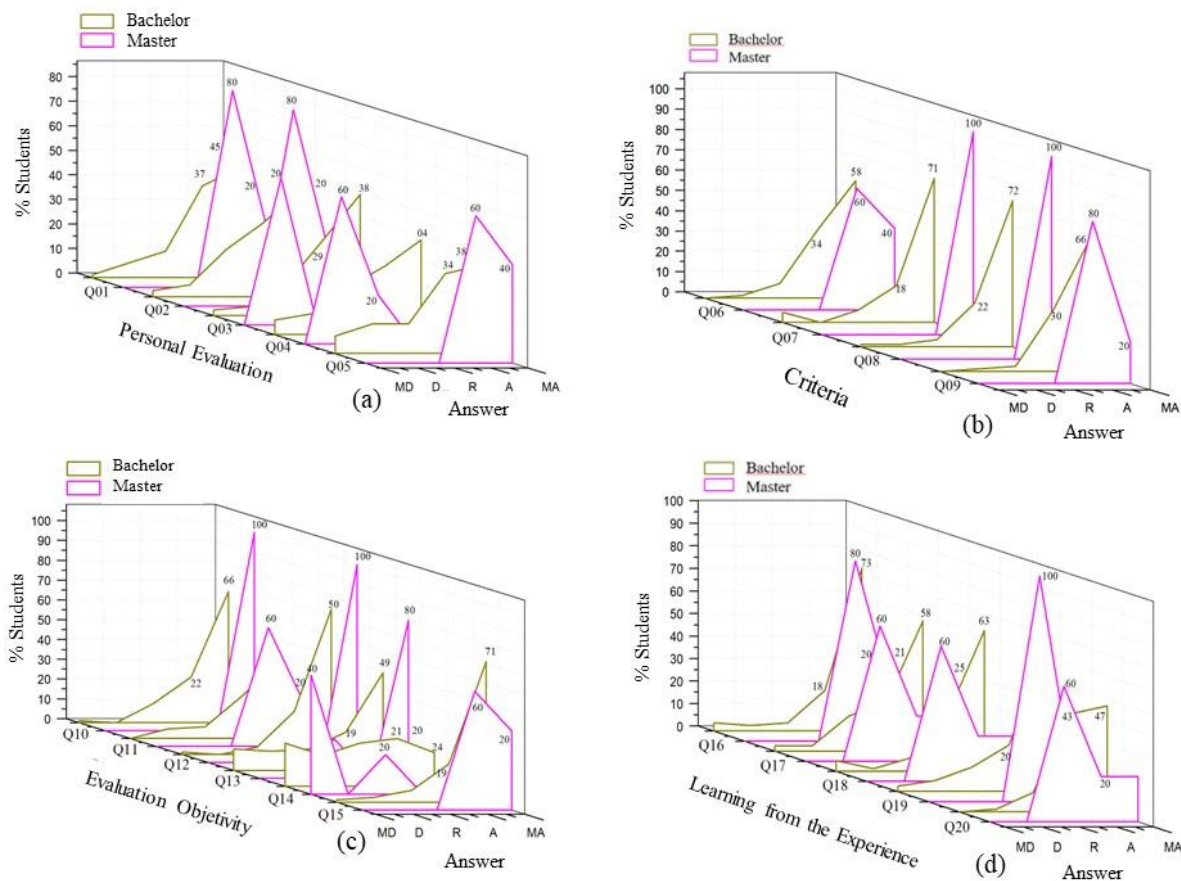
Data used for this analysis is presented in Figure 8. With regards to the *personal evaluation* dimension, Bachelor's students rated items Q01, Q02 and Q04 more highly, whilst Master's students scored items Q03 and Q05 more highly. This demonstrates that Master's students felt more responsible regarding their own learning and exhibit a higher degree of maturity than Bachelor's students (Q03). The former also reported that engaging in self- and co-evaluation processes provided an "extra" motivational push (Q05). In the case of the *criteria* dimension, items Q06-Q09, responses were highly positive in both cases, with slightly more positive responses coming from Master's students. The only exception to this was question Q09 (*...documents provided by teachers...*), potentially due to the fact that experience accumulated over the degree course makes Master's students more demanding when it comes to the material they expect to be provided with.

With regards to the *personal evaluation* dimension Master's students were found to exhibit greater maturity than Bachelor's students, being, for example, more critical of the documents provided by teachers and of learning generally. This finding has been reported previously by Abadía et al., (2015). It is notable that differences between Master's and Bachelor's students' satisfaction were so marked with regards to question Q04 (*... this experience helped me to improve my approach to studying...*). Master's students provided much more negative responses. This makes sense given that Master's students tend to be more autonomous and independent, whilst Bachelor's students are more likely to form study groups as an academic and moral aid. This was previously highlighted by Martínez

& Campuzano (2011) and Olds & Miller (2004) who discussed the use of peer collaboration and immersive learning as an incentive to promote greater satisfaction in engineering students and improve academic performance. In addition, similar outcomes were also observed regarding perceptions of the teacher evaluation in the *criteria* group, with standpoints being more critical in Master's students. In the case of the *evaluation*

objectivity (Q10-Q15) and *learning from the experience* (Q16-Q20) dimensions, Master's students rated items more positively than Bachelor's students, pointing to their greater independence. Question Q19 (...*would you recommend ... experience...*) was more highly rated by Bachelor's students. Both student groups leaned towards agreeing that anonymity was ensured in the evaluation.

Figure 8. Distribution of responses to the 360-degree feedback survey, according to degree level. Numerical values are reported for students who were in agreement or total agreement. Responses are grouped as a) Q01 to Q05, b) Q06 to Q10, c) Q11 to Q15 and d) Q16 to Q20.

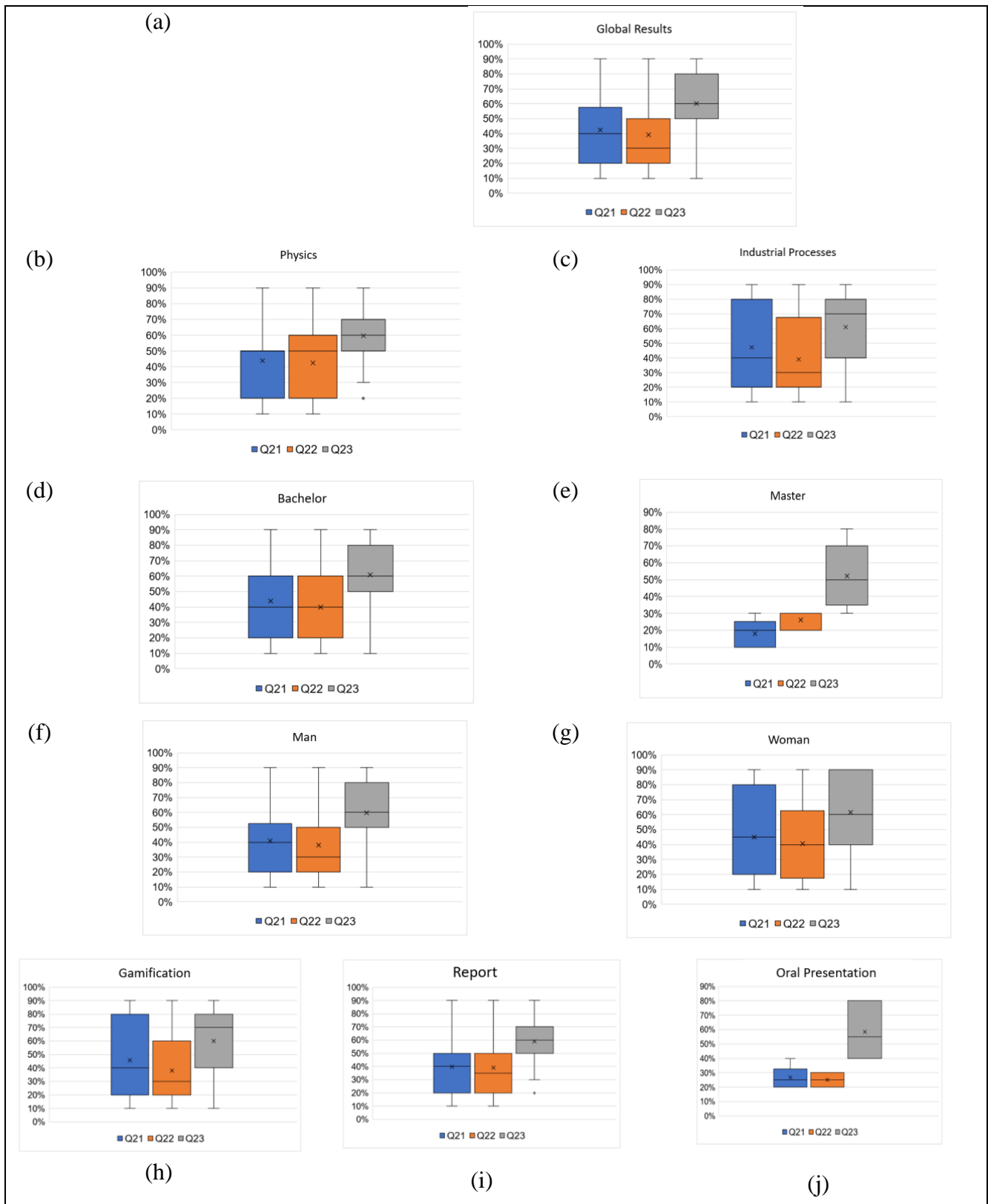


Analysis of evaluation weightings

With regards to the % that should be assigned to the different evaluations, Figure 9

presents a boxplot summary of the appropriate proportional consideration for each evaluation type.

Figure 9. Boxplot of responses Q21-Q23: (a) Responses from the overall sample; (b)-(c) responses grouped according to module; (d)-(e) responses grouped according to degree level; (f)-(g) responses grouped according to gender; y (h)-(i)-(j) responses grouped according to evaluation type.



From a global point of view, sub-figure (a), covering all student responses, reveals that self-evaluation (Q21) should, on average, account for (represented by an “x” symbol within the figure) approximately 40%. It was deemed that co-evaluation (Q22) should account for a similar proportion of around 40%. Nonetheless, the teacher evaluation (Q23) was judged to be more influential, with reports suggesting it should account for around 60%. The range of possible responses was between 10% and 90%. When analysing according to groupings, starting with analysis as a function of modules (first- or third-year modules), *first-year students* presented less dispersion in the responses given to the three questions, with the majority thinking in a fairly homogenous way, *relative to third-year students who displayed* greater dispersion. These differences in dispersion are noticeable, above all, in the weightings deemed to be appropriate for self-evaluation. In this case, first-year students shared a more similar way of thinking.

With regards to degree course (see sub-figures [d] and [e]), outcomes pertaining to Bachelor’s students are highly similar to the general outcomes, with a fairly high amount of dispersion between responses. In contrast, Master’s students’ responses were less dispersed for items Q21 and Q22, with a range of around 20% and 30%, respectively. Weightings were lower than those reported by Bachelor’s students, with teacher performance also being given lesser weight (around 50%). With regards to analysis as a function of sex (see sub-figures [f] and [g]), highly similar average evaluation weightings were observed, however, more dispersion was seen between the responses given by females than those given by males, with greater disagreement emerging with regards to the % to be applied to each evaluation type. Despite this, males and females ending up giving highly similar average responses. Finally, evaluation weightings according to evaluation model (see subfigures [h], [i] and [j]) reveal a lack of agreement within the *gamification* modality, slightly more agreement in the *written report*

modality and clear agreement in the *oral presentation* modality regarding self- and co-evaluation weightings, although, in the latter, a lack of agreement existed regarding weighting of the teacher evaluation. As a general conclusion, as expected, it is clear that the teacher evaluation weighting must always be greater than 50%, with a lack of clarity remaining around whether the standpoint of students supports a greater weighting being given to self-evaluation or co-evaluation.

Conclusions

The present work reports the systematic application of a 360-degree feedback evaluation methodology in different engineering modules belonging to the industrial knowledge branch. Satisfaction was quantitatively assessed in different student groups (according to academic year, sex and evaluation method), alongside an analysis of the weightings deemed to be appropriate by these groupings to apply to hetero-, self- and co-evaluation. More specifically, responses were analysed within the different groupings as a function of one first-year and one third-year module, as well as according to sex (female or male), evaluation method (written report, gamification or oral presentation) and degree level (Bachelor’s or Master’s). This analysis enabled identification of student satisfaction with this methodology. Likewise, findings shed light on the huge similarities existing between the evaluative criteria deemed to be suitable by both students (co- and self- evaluation) and teachers (hetero-evaluation).

Confirmatory factor analysis conducted of survey items confirmed their validity, whilst their consistency was verified through Cronbach alpha and Guttman lambda-6 outcomes, with resultant values being acceptably high. The weightings considered by students to give the fairest representation of evaluation outcomes was also analysed according to response dispersion, making it possible to identify, not only, their opinions but, also, the degree of agreement between all opinions. The most negatively rated items

corresponded to the impact of anonymity in evaluation, although analysis of responses as a function of the grouping separating two modules from different academic years (1st and 3rd) revealed greater academic maturity in students with more university experience (3rd). This highlights that third-year students have more realistic and critical perceptions of the 360-degree feedback process. In addition, Master's students perceived themselves to be more responsible for their own learning than did Bachelor's students, although these students were also found to be more demanding regarding the documentation provided to them by teaching staff. Outcomes from the sex-based analysis revealed that females were more positive than males regarding *evaluation objectivity*. This may be due to them having a slightly greater sense of responsibility and fairness, due to socio-cultural contexts, however, such conclusions are hard to demonstrate and could be trivial. With regards to evaluation modality, it is emphasised that 100% of those surveyed who had given an oral presentation believed the evaluation experience to be enriching and deemed self-evaluation to be a fair way of conducting an evaluation (almost certainly due to the majority being Master's students and, therefore, being less modest and more capable when it comes to delivering a presentation in front of an audience). In contrast, 80% of students evaluated through gamification and a written report considered the criteria and documentation provided to conduct the evaluation to be highly suitable. Not a single student from the different evaluation modalities disagreed with the evaluation criteria provided by teachers for 360-degree feedback.

With regards to the weighting to be given to each evaluation type in order to reach a final score, findings are somewhat logical and sensible in the sense that teacher ratings hold more importance than ratings from other sources. Indeed, findings revealed that the teacher evaluation should be given a weighting of at least 50%. Nonetheless, consensus was not unanimous with regards to the actual value

thought to be appropriate by the analysed groups. Similarly, no clear agreement was found between students regarding the weight to be given to their own self-evaluations. Nonetheless, accepting that Master's students are capable of demonstrating greater maturity (as confirmed by the survey responses described above), the average weightings proposed by participating students can be taken as valid. Specifically, these weightings were 20% for self-evaluation and 30% for co-evaluation, leaving 50% for teacher evaluations.

This methodology, therefore, implies a degree of pro-activeness on behalf of students in engaging in their own evaluation, with the concomitant motivation to stand out during the process.

By way of a final summary, a survey designed to analyse the application of a 360-degree feedback methodology within industrial engineering degree courses was demonstrated to be fairly reliable and useful for evaluating student satisfaction. This opens doors to the expansion and standardisation of this methodology for its use in other courses, potentially contributing fairer evaluation tools and, therefore, providing students with an extra motivational push. It is hoped that this will help reduce dropout rates and increase the number of new intakes enrolled on the course. A limitation of the present study that should be mentioned is that it was not possible to quantitatively correlate satisfaction with greater academic success, although previously conducted studies have managed to demonstrate a positive impact of the present type of methodology on student learning (Basurto-Mendoza et al., 2021; Vivanco-Álvarez & Pinto-Vilca, 2018).

Generally speaking, outcomes appear to confirm one of the study objectives: the present evaluation was considered by students to be useful, fair, coherent and attractive. This outcome appears to be a specific achievement of the present methodology, managing to awaken greater interest in students. Findings also suggest that a weighting balance of 50%-

20%-30% (hetero-, self- and co-evaluation, respectively) may be the fairest, in consideration of the opinions of students from each grouping.

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