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Towards skill-based evaluation in a hybrid learning context: an experience in Aircraft Maintenance

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Abstract

COVID-19 forced Higher Education to take place virtually. The evaluation process was particularly sensitive, mainly if it involved written tests. Still, it posed an opportunity to revise learning activities and evaluations. The Aircraft Maintenance course at UPV was driven from a content-based evaluation toward a skill-based one, replacing an open-answer test with a thorough assignment. Student grades and surveys motivated the perpetuation of the activity once students were back in a classroom.

Keywords: skill-based evaluation; hybrid learning; aircraft maintenance; written reports

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1. Introduction and Objectives

As opposed to the traditional content-based learning methodologies, skill-based learning aims at building knowledge by developing practical expertise in a particular area. According to Baeten et al. (2010) this learning method and the use of active methodologies end up relating to the so-called *deep learning* in contrast to *surface learning*, allowing students to think critically and communicate effectively with others as well as developing them as lifelong learners. Some authors such as Scouller (1998) or Molina et al. (2014) found the assessment methods have a substantial impact on the

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approaches taken by students to a subject, with multiple choice examinations encouraging surface learning and assignment essays assessing higher levels of cognitive processing. The present work depicts an experience of replacing an open-answer test by a thorough written assignment in search of deep learning in an Aircraft Maintenance course.

The Aircraft Maintenance course at Universitat Politècnica de València (UPV) belongs to the 4th year (8th semester) of the "Aircraft" specialty corresponding to the Degree in Aerospace Engineering, with an enrolment rate of 45-50 students per year. It is conceived to provide students with knowledge of defining maintenance in design and to develop the ability to maintain the airworthiness of an aircraft fleet. Additionally, UPV (2015) designed a project in which 13 soft skills were defined to be acquired by the students throughout the Degree. The Aircraft Maintenance Course course, therefore, seeks to obtain a set of both specific and soft skills.

The main specific learning outcomes of the course are the following:

- Fundamentals of maintainability of an aircraft design.
- Maintenance of existing aerospace vehicles, powerplants, systems and facilities.
- Ability to apply regulations in the exercise of the professional duties of an aerospace engineer.

To achieve such specific skills, the contents of the course are divided into two main modules:

- *Fundamentals of Maintenance Engineering*, devoted to the study of the evolution of the maintenance engineering paradigms (with a special devotion to Reliability-Centered Maintenance –RCM- due to its importance in aviation) and the statistical study of reliability and failure rates.
- *Aircraft Maintenance Management*, devoted to the introduction of the relevant aircraft maintenance regulations and their practical application in base maintenance, line maintenance and component maintenance (the three pillars of aircraft maintenance) in the context of a typical mid-sized European airline, so that the specific problems faced by maintenance managers, such as maintenance scheduling and decision-making, naturally arise.

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Additionally, the Aircraft Maintenance course includes activities related to the following soft skills:

- To act with *Ethical, environmental, and professional responsibility.*
- *Effective communication*: to use convenient resources and adapt them to each situation and audience in orderto communicate the intended ideas effectively, both orally and in writing.
- *Knowledge of current issues*: to identify and interpret contemporary problems, paying particular attention to aspects related to sustainability in the field of specialization.
- *Planning and time management*: adequately schedule the activities required to achieve the objectives within the available time.

Assessments are an essential point in demonstrating whether a learning outcome has been achieved. On the one hand, a sound assessment system gives students confidence in the quality of their training. On the other hand, it encourages employers to have confidence in accredited students. Until the 2018/19 academic year, learning outcomes in the Aircraft Maintenance course were mainly assessed through multiple-choice tests (40% of the course) for each module, a problem-based test for the first module (25%), and an open-response test for the second module (25%). Active methodologies were only used in the lab session reports (10%), as covered by García-Cuevas et al. (2016), and most learning and assessment activities were content-based. The COVID-19 pandemic forced a virtual environment by the time the second module was developed in the 2019/20 academic year. This context did not encourage assessment through an open-ended test. Far from being a problem, shifting from face-to-face activities to remote or hybrid learning contexts was perceived as an opportunity to review the course activities and begin to steer them toward skills-based tasks and assessments. This opportunity was also seen elsewhere, as done by Ayuningtyas et al. (2020). Hence, the second open-response test was replaced by a written assignment that would force students to train and develop the ability to understand and apply continuing airworthiness regulations.

The ultimate objective of the investigation is to assess whether the implemented methodology forces students to adopt a *deep learning* approach towards the course rather than a *surface-based*

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one, allowing them to attain a lifelong learning skill related to United Nations Sustainable Development Goal (UN SDG) 4. Hence, the specific objectives are:

- To propose a methodology that allows steering a course towards active learning.
- To gather evidence about the impact of the activity on student performance and opinion.
- To analyze the results to the extent that confirms if the proposed activity can be considered as a skill-based learning methodology rather than a content-based methodology.

To develop a student's lifelong learning attitude towards aircraft maintenance that raises awareness on the opportunities of these disciplines in terms of UN SDGs 8 (Decent Work and Economic Growth) and 13 (Climate Action).

2. Methodology

The aforementioned module of Aircraft Maintenance Management is built around regulations concerning airworthiness, gathered by Cuerno (2008). In particular, EU regulations 748/2012 (airworthiness certification) and, especially, 1321/2014 (continuing airworthiness), and their successive amendments. Considering how important but challenging it is to teach technical regulations in engineering, this module is considered ideal to shift the assessment from an exam with open-ended questions to a written task and thus promote students' deep learning in this matter, which is the objective of this investigation.

The new written assignment for the course of Aircraft Maintenance was defined following the guidelines of other successful experiences in the framework of the Aerospace Engineering BSc, such as the one described by Carreres et al. (2019). This way, the assignment's statement was provided two months before the deadline. 13 topics about aircraft maintenance are randomly assigned to the students on the day that the assignment is described in class. Each student should upload in due time a report about one of these contents: EASA vs FAA regulations, initial vs continuing airworthiness, Part M Subpart G vs Part M Subpart F vs Part 145, requirements for the update of Part M organizations, aircraft maintenance records, quality system, aircraft reliability program, personnel training requirements, line vs base maintenance, material support, component maintenance, design

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for maintainability and design and programming of maintenance checks. Therefore, the assignment is an opportunity for the students to dive deep into topics addressed in the theory lessons that would be important for a future career in aircraft maintenance. Besides, by working on maintenance problems in the scope of current legislation and having to deliver reports with submission deadlines, the students improve their abilities in the soft skills of *Knowledge of current issues* and *Planning and time management*, as mentioned in the Introduction.

For instance, regarding the topic of aircraft maintenance records, the assignment statement specifies the questions that a student report should answer based on the corresponding regulations:

- Which types of tasks require maintenance records to be kept?
- Indicate which records should be kept by each type of organization involved in continuing airworthiness maintenance, emphasizing the differences.
- Specify for how long, where, and under what conditions maintenance records must be kept by each organization involved.
- Analyze what happens if an airline buys a used aircraft from another operator and when a private individual buys a used aircraft from another private individual.
- Show an example of a maintenance record, analyzing the information it contains.

The assignment's statement includes recommendations about the contents (as aforementioned) and the approach of the report. Nevertheless, students are encouraged to ask the teacher for support whenever required. In any case, an intermediate delivery of an unfinished version of the report is welcome by the teacher to provide feedback before the deadline, as it has been shown to improve the result of the final report (Carreres, 2019). Besides, the scoring rubrics used for evaluating each work are provided in advance to encourage student self-assessment. The dimensions of these rubrics are:

- Development of the assigned contents.
- Identification of relevant regulations.
- Identification and interpretation of relevant Acceptable Means of Compliance (AMCs). Please note that AMCs constitute EASA's own interpretation of the regulations (where EASA is Europe's organism with legislating capabilities in aircraft maintenance) and are gathered in additional documents separated from the regulations themselves.

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- Ability to relate the work with the course contents.
- Usage of real cases as examples.
- Readability and usage of technical terms.

For instance, how well the students can identify regulations relevant to their academic assignment is assessed with 4 levels:

- *Perfectly*, if all the legislation relevant to the selected topic is identified.
- *Well*, if most of the relevant regulations for the assignment topic are identified, although there are some minor errors, e.g., legislation that is not relevant is mentioned.
- *Fairly*, if some applicable legislation is omitted or the relevant regulations are misidentified (e.g., considering old instead of current legislation).
- *Inadequately*, if the regulations that apply in the scope of the topic are barely included or severely misidentified.

Please note that the academic assignment trains the students not only in the technical aspects of a course in aircraft maintenance but also in the soft skill of *Effective communication* mentioned in the Introduction. For the latter, the students are provided with a set of guidelines for written reports. They are also assessed in terms of soft skills with scoring rubrics. For instance, 4 different levels of performance can be obtained for the Effective communication skill, described as follows:

- *Excellent*, if the ideas are perfectly presented, the text is free from grammatical mistakes and always uses the most appropriate technical terms, and the format is appealing.
- *Adequate*, if the ideas are clearly presented, the text includes some minor mistakes and uses technical language when it corresponds, and the format is good.
- *In development*, if the ideas presented can be understood with little effort, the text includes some mistakes and sometimes uses the corresponding technical language, and the format hinders the understanding of some graphs or tables.
- *Not achieved*, if the ideas presented cannot be adequately understood, the text includes serious mistakes and seldom uses the corresponding technical language (or misuses some technical terms), and the format makes it impossible to read some of the graphs and tables.

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3. Results

The implementation of the new learning methodology is evaluated from two different points of view. On the one hand, the results obtained by the students using the proposed learning methodology are compared to those obtained using the traditional one. On the other hand, the students' opinion is also analyzed with the objective of identifying whether the new methodology motivates and encourages active student participation toward *deep learning*.

3.1. Students' evaluation results

Results obtained by the students after the evaluation process are analyzed in Fig. 1. Here, a comparison between the conventional methodology -based on open-answer tests- and the proposed method over three consecutive academic years is shown. The graph on the left-hand side shows the distribution of the grades obtained by the students for the evaluation of the second module. Inspection of the distribution itself does not seem to aid in understanding whether the methodology helps to improve the students' marks. However, the average value of the rates slightly increased during the two academic years following the application of the new method (0.2 and 0.22, respectively). In addition, the success percentage of the corresponding activity rose to 98% in this period (around a 9% of improvement). Nevertheless, data from the last academic year show a reduction in both metrics, returning to values comparable to those obtained prior to the application of the methodology. This could be attributed to the distribution of the academic calendar, since a more exhaustive analysis of the data revealed that the effective time for the written assessment (WA) completion was significantly less in this last year (WA Y-III). This fact, not controlled by the teachers, was found to directly compromise the quality of the work and indirectly condition the learning process. Hence, it could point out the need for horizontal coordination among professors sharing a semester in the degree. Nevertheless, firm conclusions on the matter would require a specific research study, out of the scope of the present investigation.

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To quantify the impact of the results on the overall acquisition of course skills, the graph on the right shows the results of the complete evaluation process. In this case, the average rates remained in a similar range throughout the years (0.2 standard deviation over the 4 academic years). In contrast, the percentage of success of the course improved significantly after the application of the methodology (from 95.7% to 98.0%), and it has been maintained in subsequent years.

These results may not be conclusive, as raw data from four different courses are being compared. In the long term, the impact of the assessment shift will be determined based on data from subsequent years. In any case, Fig. 1 shows an overall improvement in the results, suggesting that the methodology contributes to a better student acquisition of content and skills.

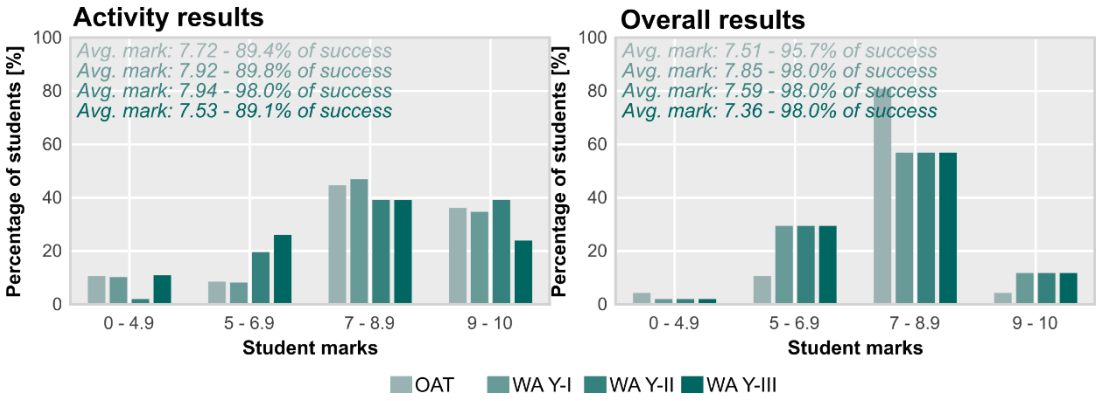

Figure 1. Results of the second module (left) and overall (right) evaluation procedures. Legend: Open Answer Test (OAT), Written Assessment (WA Y-I, Y-II, Y-III).

3.2. Subjective students' opinion

The subjective feedback from the students is ranged by a survey in which their perception about different aspects of the learning methodology is assessed. Student opinions were gathered at the end of the course through an anonymous poll, in which they were asked about critical aspects related to the application of the learning methodology. Table 1 shows the 8 questions posed to the students in this anonymous poll in order to evaluate the impact of the methodology.

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Table 1. Poll questions.

Question #	Statement
Q.1	The methodology contributed to my achievement of the learning outcomes and acquisition of the course skills.
Q.2	The methodology contributed to my achievement of the learning outcomes to a greater extent than an open-answer test.
Q.3	The time I had to devote to the academic assignment is in line with what the professor indicated.
Q.4	I devoted more time to the report elaboration than I would have had to devote to an open-answer test.
Q.5	I am satisfied with the evaluation of my academic report.
Q.6	I feel that I received a higher grade than I would have received on an open-answer test.
Q.7	I found the possibility of the intermediate submission and the feedback from the professor helpful.
Q.8	Overall, I liked the experience of this methodology.

Figure 2 shows the percentage of students agreeing with the specific statements in the last academic years (Y-II and Y-III), demonstrating a high degree of satisfaction with the new methodological environment. The high percentage of satisfaction is evident, indicating that the proposed methodology is well-received by aerospace engineering students. For example, the results of questions Q.1 and Q.2, focused on the acquisition of skills, show remarkably high percentages (above 75%) during the second academic year (left graph), which shows that the methodology helps students in the learning process. These values are even higher over the last year (Y-III), reaching values around 80% of satisfaction.

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Results for questions Q.3 and Q.4 are related to the time spent performing the written assignment. Students generally agree with the professor's indications about the time needed for the report realization during the Y-II. However, they also feel that the time required is higher than preparing for an open-answer test (OAT). These results notably changed during the last year (Y-III), where it no longer seems so evident that the time needed for the report realization coincides with the professor's explanations. Similarly, there is no clear consensus as to which evaluation method is the shortest: open-answer test versus written assignment. This generalized change concerning execution times evidences a clear difference between the two academic years, which may explain the drop in the grades seen in the previous section. As explained before, the distribution of the academic calendar in Y-III effectively reduced the time available for the students to complete the assignment.

Regarding the evaluation process, questions Q.5, Q.6, and Q.7 summarize the overall opinion. The trends are similar to those seen in questions Q.3 and Q.4. There is a clear tendency to cast the validity of the methodology in the last year. However, the overall level of satisfaction, evaluated in Q.8, remains at comparable levels, above 70% in both years.

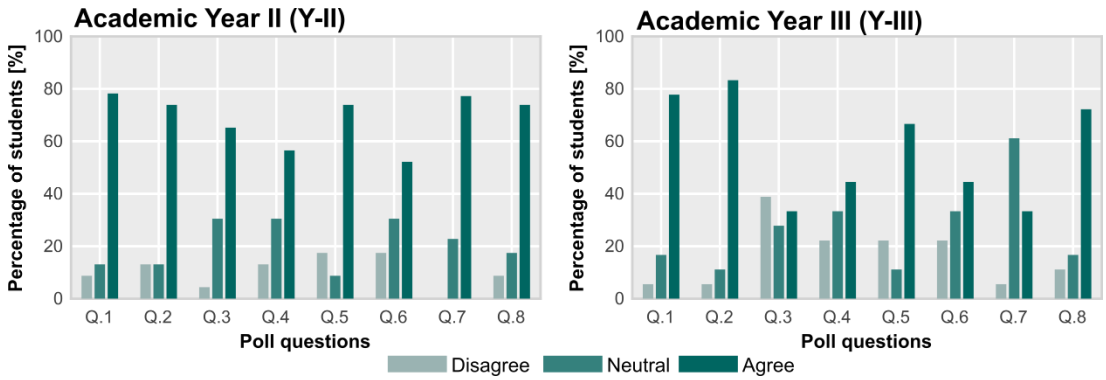

Figure 2. Anonymous poll results.

Questions Q.1, Q.2 and Q.8 are the most relevant from the point of view of the acquisition of skills and student engagement. The results for these particular questions (agreement greater than 70% in all of them regardless of the considered year) suggest that the used methodology has a direct consequence on learning in the Aircraft Maintenance course. Thanks to the developed methodology,

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there is a greater satisfaction in the student's understanding compared to the previous open-exam methodology, that could hinder reasoning and knowledge integration, for which the new strategy provides help.

4. Conclusions

The present work attempted to investigate the effect of steering the evaluation from *content-based* (open-answer test) to *skill-based* (written assignment forcing to navigate and integrate regulation text) on the acquisition of learning outcomes by students. The new assignment also contributes to the acquisition of three soft skills and is a more remote and digital-friendly activity, as it was motivated by the shift from on-site teaching to virtual or hybrid learning contexts due to the COVID-19 pandemic, already described by Erdmann et al. (2021).

The discussed evidences are based on comparing the grades achieved by the students through both evaluations on the one hand, and analyzing their responses to a student survey about the topic on the other hand.

Results show that the average assignment grades were only slightly greater than their open-answer test counterpart, although the success rate was improved. Anyway, the student opinion strongly reinforces the idea that *skill-based* evaluation was achieved, encouraging *deep learning* to a higher extent as suggested by works in the literature such as the one by Scouller (1998).

In any case, some possible limitations to the implementation of the methodology must be discussed, together with improvements and future works to counter them. On the one hand, a certain dependence between the results offered by the methodology and the academic calendar has been observed. Both the objective results and the students' opinion seem to be conditioned by the time available to prepare the written assignment in which the evaluation process is based. It is then suggested to provide the statement of the assignment together with its calendar well in advance, and devote some time in class to explain the assignment details especially before the important dates (group formation -if any-, submission deadlines, etc.). Additionally, the investigation showed that the

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students required more time to prepare the written assignment than they would have devoted to an open-answer test. If the methodology was implemented in different courses, the student workload could increase beyond a reasonable amount. Coordination between professors of the different courses shared during the semester would be an aspect to be taken into account in order to improve the scope and robustness of the methodology, especially as far as the previous limitations are concerned. On the other hand, the methodology has been assessed on the basis of 3 academic years. As future work, the indicators studied in the investigation should be monitored for a longer period. This would also help understanding the discussed limitations and identifying whether the proposed improvements are effective against them.

Finally, it is important to note that the presented methodology is not restricted to *replacing a test by an assignment*, but is rather based on designing an activity that demands students to demonstrate their skills on the course through reflection and synthesis, in a process in which the teacher must accompany the student providing help and regular feedback. In order to prevent the effect of this activity to dilute as new students get access to work from former students, the assignment contents should be renewed along the years.

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