

# INTED **2019**

## 13th International Technology, Education and Development Conference

11-13 March, 2019  
Valencia (Spain)

# CONFERENCE PROCEEDINGS



*Exploring New Frontiers in Education*

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**Published by**  
IATED Academy  
iated.org

**INTED2019 Proceedings**  
13th International Technology, Education and Development Conference  
March 11th-13th, 2019 — Valencia, Spain

**Edited by**  
L. Gómez Chova, A. López Martínez, I. Candel Torres  
IATED Academy

DOI: 10.21125/inted.2019  
ISBN: 978-84-09-08619-1  
ISSN: 2340-1079  
Depósito Legal: V-247-2019

Book cover designed by  
J.L. Bernat

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**ASSESSMENT OF INSTRUMENTAL SKILLS AND CAPACITY TO USE THE TECHNIQUES AND TOOLS IN PRACTICE WITHIN A SUBJECT RELATED TO MECHANICAL ENGINEERING****J. Giner-Navarro<sup>1</sup>, A. Sonseca<sup>1</sup>, J. Carballeira<sup>1</sup>, J. Martínez-Casas<sup>1</sup>***<sup>1</sup>Departamento de Ingeniería Mecánica y de Materiales, Universitat Politècnica de València (UPV), Camino de Vera s/nº, 46022 Valencia (Spain)***Abstract**

Over the last few years there is a high interest in developing new curricular programmes of the European Higher Education Area that adapt their masters' and bachelors' degrees to the demands of the employers. The international accreditation of these programmes is not limited to the evaluation of the subjects within the degrees, it also scores the generic and specific competences that will be achieved by the students. These competences are thought to evaluate what the students are actually able to do and therefore, they are useful not only to adapt the degrees to the existing European working model, but also to facilitate the students' incorporation into it. Nevertheless, the methodologies for the assessment of these competences are still a pending task that requires more learning experience. In order to contribute to the progress of this topic, this work presents an 'outcomes' approach for the assessment of the students' ability to use the techniques, skills and tools for engineering related practical issues within mechanical engineering subjects. In particular, this paper designs individual questionnaires for IT and laboratory practices in order to quantify the domain level of the students in the usage of a commercial software and in the comprehension of technical and instrumental concepts. These tools are based on the evaluation of some learning outcomes that can be observed by using different strategies along the academic year. Some results regarding a first attempt to use this tool are also analysed in this paper. Finally, some conclusions are derived from these experiences in order to improve our proposal in the future.

Keywords: competence assessment; learning outcomes; instrumental skills.

**1 INTRODUCTION**

A competence-based approach [1,2] is extensively followed in the university system within the frame of the European Higher Education Area. The generic competences are recognised to be critical for the professional development of the students and for the social prosperity and therefore they represent an overall purpose that has to be pursued [3]. Therefore, academic institutions are conscious of the need to achieve an international accreditation of their competence-based programmes and have been working hard on this issue. More specifically, the Polytechnic University of Valencia (UPV) has defined 13 main competences in the development of its bachelors' and masters' degrees [4]. These competences are of great interest for employers to have better information of their candidates regarding not only the subjects that they have studied but also what they are actually able to do [5]. Also universities can take advantage of this information in order to promote students' mobility based on comparable evaluation criteria [6,7].

Nevertheless, the assessment of the generic competences is still a topic under research [8] as it is widely accepted that the lecture-based teaching method does not fit with the development of individual skills. Thus, a change in the current pedagogical practices is strongly required. So that, UPV has made a call for innovative projects in this regard (PIME program).

Within the frame of one of these projects, this work presents some preliminary results obtained from the learning experience. In the authors' opinion, the use of learning-oriented active methodologies is essential to force the students to put their skills into play by means of evaluation activities that permit a direct evaluation of the required competences. In this line, this paper intends to develop strategies and tools for the assessment of one generic competence that has not been previously worked in mechanical engineering subjects: "Specific Instrumental". This is how it is denominated at UPV and, although there is not direct conversion into the list of generic competences of Tuning [9,10] or ABET [11,12] projects, its characteristics fit with "Technology Skills" or "Technical Skills". This competence refers to the use of needed tools and technologies for the professional practice associated with mechanical engineering. The student will be able to identify the most appropriate tools in each case, knowing their utilities and being able to integrate and combine them to solve a problem and perform a project or an experiment.

In order to facilitate the evaluation of the generic competences, our university has established three different levels of development for every competence that cover from the first and second (Level 1) and the third and fourth (Level 2) years in bachelors' degree, to last year of studies corresponding to masters' degree (Level 3). The complexity of the learning outcomes associated to these competences increases with these levels [4]. In this paper, two subjects of the first year of two different masters' degrees are assessed, hence corresponding with Level 3.

Both subjects deal with mechanical concepts, hence their labwork parts are essentially connected with the specific instrumental competence. For this reason, the main objective of this work is to study either, if the selected competence (instrumental skills) can be evaluated directly through the labwork mark or on the contrary a separated and specific information of its associated skills cannot be obtained. In order to do that, a systematic tool based on a checklist questionnaire also including open questions has been designed and proposed as an assessment tool. The different items intend to evaluate the technical concepts acquired during the engineering practices, which are divided in computer (using specialised software), and instrumental labwork sessions.

## 2 METHODOLOGY

As mentioned, the assessment tool proposed in this work has been tested in two different subjects of technical nature. The first one is Vibrations II, studied during the first year of the Masters' degree in Aeronautical Engineering; the second one is Machine Design, studied during the first year of the Masters' degree in Mechatronics Engineering. Both hence belong to Level 3, whose main learning outcome is as follows: *Integrate correctly the advanced tools of the professional field.*

As seen in Table 1, this domain level establishes three different indicators: 1) identification of advanced tools and their utility; 2) levels of handling of the advanced tools, and internalization of contents; 3) ability to select and combine the proper tools to carry out a professional research project. Each of these learning outcomes are itself divided into four levels of achievement as seen in Table 1: "D. Not reached", "C. In development", "B. Good/adequate" and "A. Excellent/exemplary". The numerical values intervals of 0–2.5, 2.6–5.0, 5.1–7.5, 7.6–10 are ascribed to each level, respectively. Consequently, depending on skills reflected in the total mark obtained from the questionnaire, the student will achieve one competence level or another. The indicator 2 is directly evaluated from the mark of the corresponding computer or instrumental labwork sessions. The indicators 1 and 3 are assessed from a set of specific questions in the form of two checklist questionnaires detailed in Tables 2 and 3. Both questionnaires must be answered individually. It is important to note that these questionnaires were not considered in the calculation of the final mark of the subject in order to detect in a relaxed context the knowledge acquired by the students.



Table 1. Learning outcome: argue the relevance of the judgments issued in complex approaches [4].

| LEARNING OUTCOMES   | D. Not reached   | C. Developing  | B. Good/adequate   | A. Excellent/exemplary   | EVIDENCES  |
|---|--|--|--|--|--|
| <i>Identify advanced tools and their utility</i>  | The student does not identify the advanced tools                                 | The student identifies advanced tools but does not recognize his utility   | The student identifies advanced tools and their main function                                | The student identifies additional functions of advanced tools  | Performs the practice correctly, using the proper tools. In addition, is able to answer two or three questions to identify the tools and recognize their usefulness  |
| <i>Handle advanced tools</i>  | The student is not able to handle the tools without detailed instructions        | The student handles the tools following detailed instructions  | The student handles tools autonomously   | The student handles tools with ease, exploiting all their functionalities  | Performs the task following the sequence of steps correctly and autonomously.<br>Presents an activity report with questions describing what he/she were doing, records and interprets the results  |
| <i>Select and combine the right tools to carry out a professional or research project</i> | The student does not identify the right tools for the development of the project | The student identifies the tools to be used but does not combine them adequately for the full development of the project | The student properly combines the different tools to complete the development of the project | The student finds new ways to combine tools for complete the project in the most appropriate way possible, valuing its pros and cons | Solves a problem using and combining the proper tools, when the activity requires it.<br>Answers questionnaires of two or three questions.<br>Makes a report with a reasoned description about how he/she selected and combined the different tools to solve the problem |

## 2.1 Computer labworks

The practice sessions of Vibrations II (Masters' in Aeronautical Engineering) are evaluated from a report that the students have to deliver within a week. They are asked to analyse the results and graphics obtained with Matlab© numerical software during the sessions. The resolution methodology is explained in the report of the practice, so the differential factor in the score is determined by the justification of the results computed according to the theoretical framework of the subject.

The first questionnaire, gathered in Table 2, proposes a set of questions focused on the potentialities of the numerical software Matlab. The questions are mainly oriented towards procedural methodologies to address the resolution of general or specific problems previously presented in class; the student should select the most convenient software to address these engineering problems in an efficient way. Through these questions, the extent to which the student knows the limitations of the software and its adequacy to address different types of problems are expected to be detected. Therefore, this first part of the questionnaire will permit to assess the indicators 1) identification of advanced tools and their utility, 3) ability to select and combine the proper tools to carry out a professional research project.

*Table 2. Assessment tool for Vibrations II. Computer labworks: checklist questionnaire.*

|   |
|---|
| <p><b>I1. Identify advanced tools and their utility.</b></p> <p>I1.1 In which of the following study cases do you see the use of Matlab more convenient?</p> <ul style="list-style-type: none"> <li>a) Finite Element mesh of a piece of industrial scope.</li> <li>b) Numerical integration in the time domain of the equation of motion of a mechanical system.</li> <li>c) 3D design of a piece of industrial scope.</li> </ul> <p>I1.2 Which software do you think that is more suitable to carry out the Finite Element meshing of a solid?</p> <ul style="list-style-type: none"> <li>a) Matlab.</li> <li>b) Mathematica.</li> <li>c) Ansys.</li> </ul> <p>I1.3 For which case is Matlab a flexible and adequate tool?</p> <ul style="list-style-type: none"> <li>a) Numerical integration.</li> <li>b) Design of manufacturing processes.</li> <li>c) Geometric modelling.</li> </ul> <p>I1.4 Is Matlab a useful tool for frequency analysis?</p> <ul style="list-style-type: none"> <li>a) No, it only works in the time domain.</li> <li>b) Only for low frequency dynamics.</li> <li>c) Yes, it is a highly recommended tool for frequency analysis.</li> </ul> |
| <p><b>I2. Handle advanced tools.</b> Labwork mark.</p>  |
| <p><b>I3. Select and combine the right tools to carry out a professional or research project.</b></p> <p>I3.1 Does Matlab allow importing geometries from other software?</p> <ul style="list-style-type: none"> <li>a) Yes, Matlab allows the calculation of the modal properties, the vibrational response, etc.</li> <li>b) Yes, but only for visualisation.</li> <li>c) No.</li> </ul> <p>I3.2 It is intended to carry out a vibration analysis of an aircraft wing. How would you approach it?</p> <ul style="list-style-type: none"> <li>a) Doing everything in Matlab.</li> <li>b) Making a Finite Element mesh in Ansys; Importing the geometric model and</li> </ul>   |



- mesh to Matlab and then carrying out the dynamic calculations.
- c) Doing everything in Ansys.

I3.3 In which case would you be interested in acquiring a Matlab license for your company department? In the case that the department is dedicated to:

- a) structural calculations.
- b) design and manufacturing.
- c) dynamic simulations of mechanisms.

I3.4 Does Matlab have a video generator to represent the vibrational response of a system?

- a) Yes, as a direct command.
- b) No, it only allows representing the modal deformations.
- c) Yes, the video is edited with different frames of the vibrational response.

I3.5 Is Matlab a software that allows generating a data acquisition routine?

- a) Yes, but it does not allow the post-processing of these data.
- b) No.
- c) Yes, and it includes packages to avoid leakage, aliasing and even graphic interface.

## 2.2 Instrumental labworks

The practice sessions outcomes of Machine Design (Masters' degree in Mechatronics Engineering) are assessed from a report that the students have to complete within the session. The report requires the calculation of the transmission ratio, speeds and torques of a vehicle gearbox, which are disassembled and reassembled by the students. These estimates are made in groups, so no significant differences are established between the students.

The second questionnaire intends to detect the degree of dexterity and understanding of the students about the operability of the equipment used in the technical part of the lessons. The questions gathered in Table 3 are designed to evaluate the previous knowledge of the students and the new concepts acquired through the practical handling of a gearbox during the session. Hence, this part of the questionnaire leads to the evaluation of the indicator 2) levels of handling of the advanced tools, and internalization of contents and, with the open questions. Two open questions are also included in order to detect the grade of internalization of the practical contents. The students are asked for a kinematic diagram of a two-axle gearbox and encouraged to propose new approaches to make the labwork more complete, leading to the evaluation of the indicator 3) ability to select and combine the proper tools to carry out a professional research project.

*Table 3. Assessment tool for Machine Design. Instrumental labworks: checklist questionnaire.*

### I1. Identify advanced tools and their utility.

I1.1 Did you know all the mechanical tools of the labwork and what they are used for?

- a) Yes.
- b) No.

I1.2 In this case, the speeder is applied in a gearbox of a car. In what other cases could the speeder be used?

- a) For the case of a mechanical transmission, in which the speed of revolution and power is maintained.
- b) In a mechanical lift, in order to have a high torque at the exit with a small electric motor at the entrance.
- c) In any situation where a power regulator is required.

### I2. Handle advanced tools. Labwork score.

### I3. Select and combine the right tools to carry out a professional or research project.

I3.1 While you were assembling, have you been curious about the inner performance of the gearbox?

- a) Yes, I have tried all the gears.
- b) Yes, with observation but without shifting gears.
- c) No.

I3.2 At the end of the labwork and with a gear engaged, have you tried to reverse the operation of the speeder (change input per output)?

- a) No, I have not tried it.
- b) Yes, and it becomes a speed multiplier or torque reducer.
- c) Yes, but I do not understand what happens internally.

I3.3 Draw the kinematic diagram of a two-axle gearbox with 5 forward gears and one reverse gear.

I3.4 In your opinion, what tools and devices would you introduce in the labwork to make it more complete? Enumerate them below.

## 3 RESULTS

### 3.1 Computer labworks

As seen in Fig. 1, the rates obtained in the labwork, corresponding with the indicator 2, are very high in almost all cases (83% above 9 out of 10). These results can be explained due to the time given to deliver the practice report: one week represents enough time for the students to search for information as well as to contrast and justify the results obtained in the computer sessions. In this line, the indicator 1 also does not introduce significant differences between the evidences. Both indicators are related with the identification and handling of the tools independently. However, results become much more dispersed for the indicator 3, which requires the selection and combination of the adequate tools to solve general engineering problems, a more complex task that establishes differences in the domain of technical skills. Fig. 2(a) shows the corresponding level of achievement gathered in Table 1 according with the preset numerical intervals. As expected, Fig. 2(b) shows that only the indicator 3 gets a B in average, while the rest are rated with A, in concordance with the greater level of requirement.

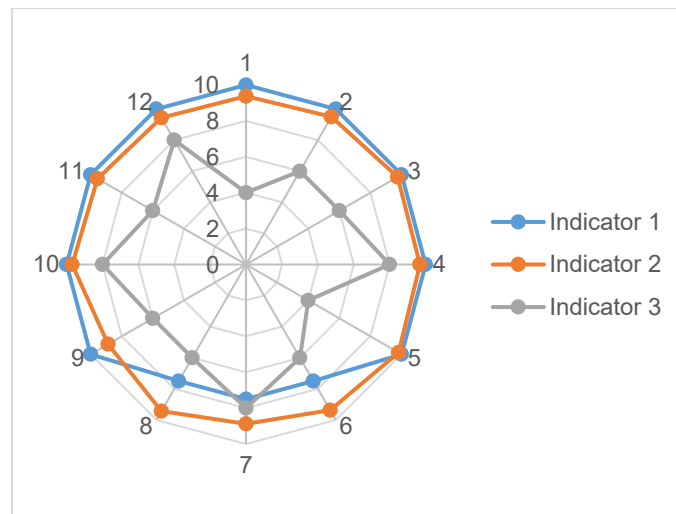


Figure 1. Rates of each indicator per evidence.

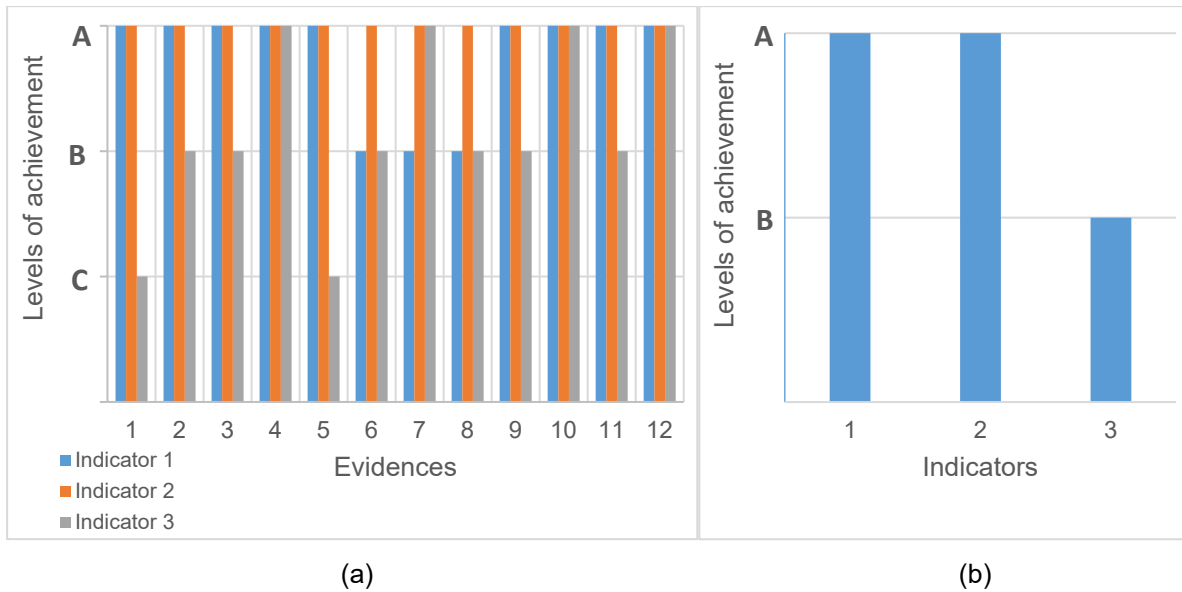


Figure 2. Level of achievement: (a) per evidence, (b) average per indicator.

The numerical mark per indicator is weighted to obtain the numerical value for the competence evaluation. Figures below (Figs. 3(a) and 3(b)) permit to observe a relation between this competence assessment and the labwork mark as both follow the same trend in most of the cases. In general, the generic competence scores decrease with lower labwork marks and increase with the higher ones. This indicates that the labwork marks are, to a certain extent, an indirect indication of the skills that correspond to the generic competence under study. Fig. 3(b) shows an offset with 1.06 point of average between both grades, without exceeding 2 points of difference. This reinforces the idea that the questionnaire is a good indicator of the skills needed to perform the labworks.

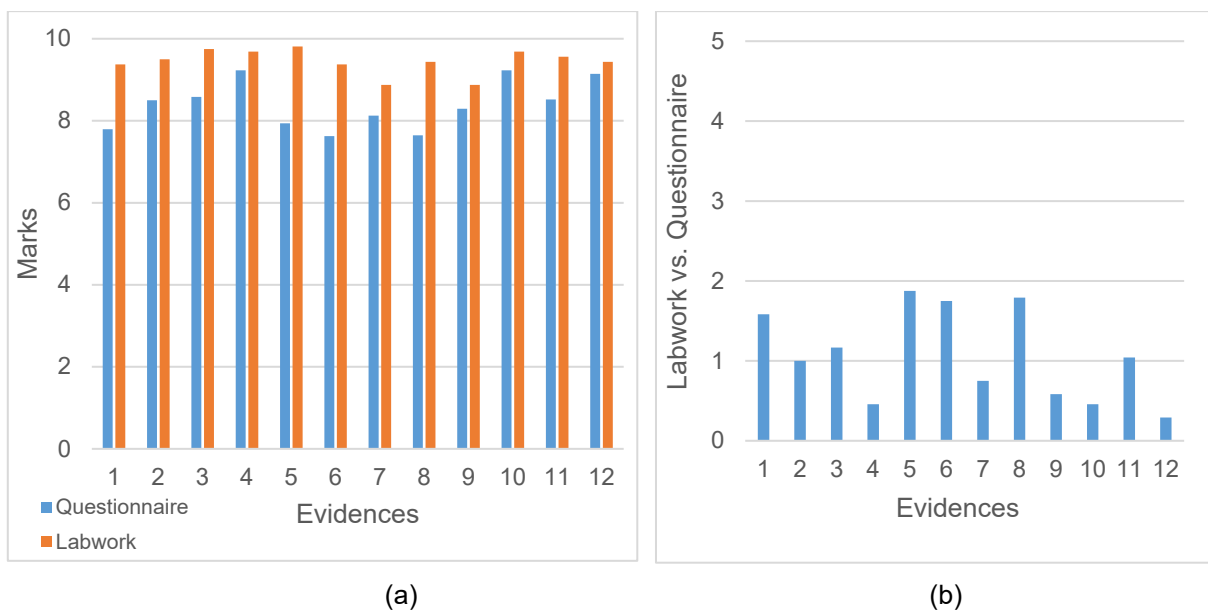


Figure 3. Comparison per evidence between questionnaire and labwork: (a) rates and (b) absolute difference between both rates per evidence.

At this point, it is studied if there is any correlation between the previous rates and the theory exam. Figs. 4 show the difference registered between the theory exam and the questionnaire and labwork evaluations. It can be observed slightly better performances in the questionnaire and labwork assessment for better theory rates, although there is not a clear correlation in all the evidences. The differences between questionnaire/labwork and theory marks are much higher, with averages 2.73 and 3.79 points, respectively. The period of one week for the delivery of practice reports has much to do with these discrepancies, together with the more difficult concepts required in the theory exam.

Obviating these differences, no correlation between the competence and the theory mark is observed, hence inferring that the results of the theory exam cannot be an indicator for the evaluation of the instrumental specific competence.

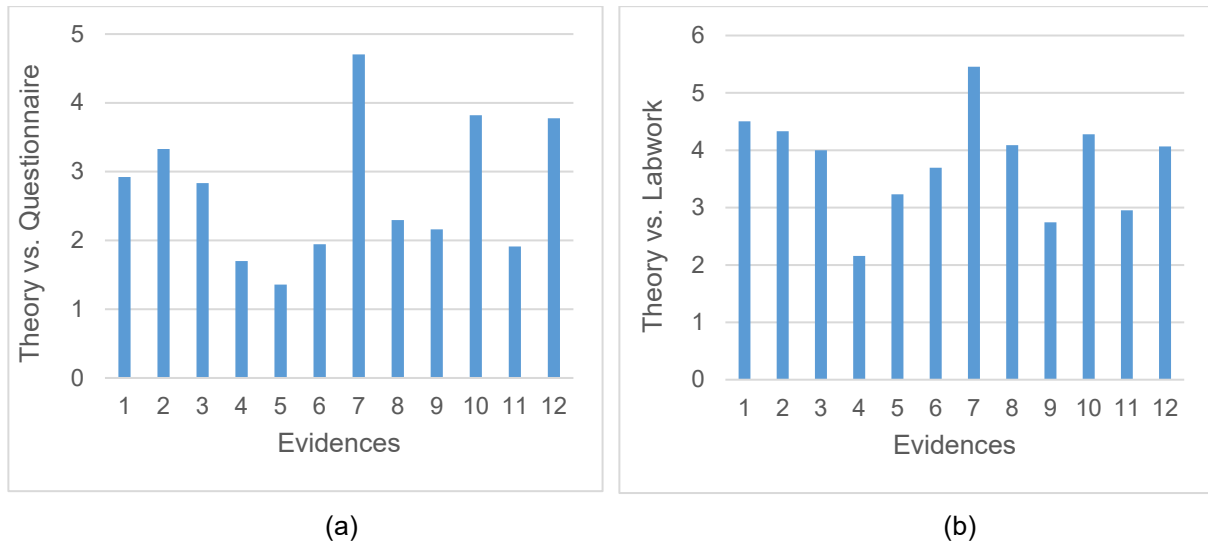


Figure 4. Comparison per evidence between theory and: (a) questionnaire, (b) labwork marks.

### 3.2 Instrumental labworks

As seen in Fig. 5, the rates obtained in the labwork, corresponding with the indicator 2, are again very high in almost all cases (87% above 9 out of 10). Indicators 1 and 2 have higher rates than indicator 3, which is again related with the selection and combination of the tools learned during the labwork sessions, thus increasing the level of demand of the corresponding competence test. This result is evidenced in Figs. 6, in which the most demanding indicator (number 3), averages a level of achievement B (Fig. 6(b)). The origin of this drop in the indicator 3 is due to the inclusion of the last two open questions; this suggests that the design of the questionnaire shows coherence with the level of requirement previously adopted.

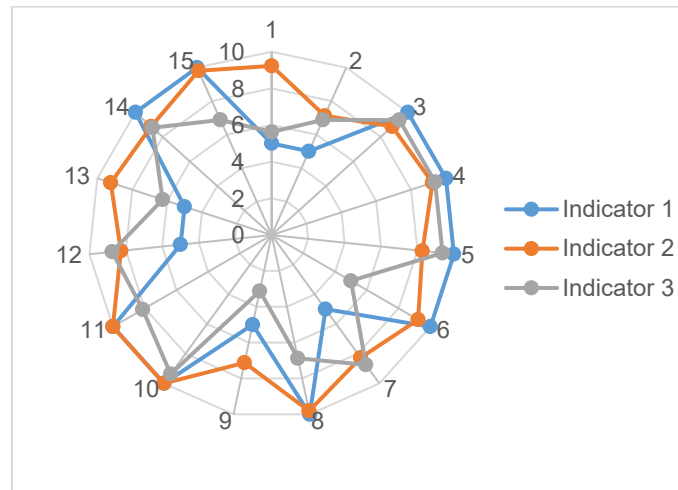


Figure 5. Rates of each indicator per evidence.

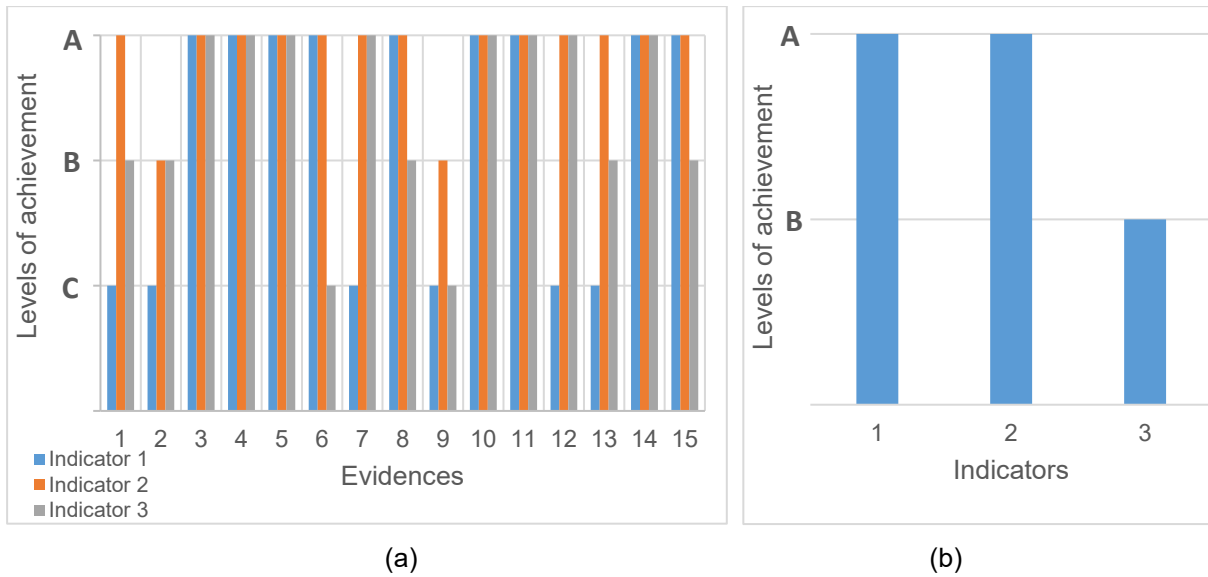


Figure 6. Level of achievement: (a) per evidence, (b) average per indicator.

As observed in Figs. 7, the comparison between the questionnaire and the labwork and theory marks results in differences below 2 points for a 73% of the evidences for the labwork vs. questionnaire, and for a 67% of the evidences for the theory vs. questionnaire. Although most of the evidences are in the 2-points range, no correlation has been established in the evolution of the marks by evidence. This fact reinforces the thesis of the need to design an independent assessment tool for the generic competence under study, since this cannot be inferred either from the labwork mark or from the theory.

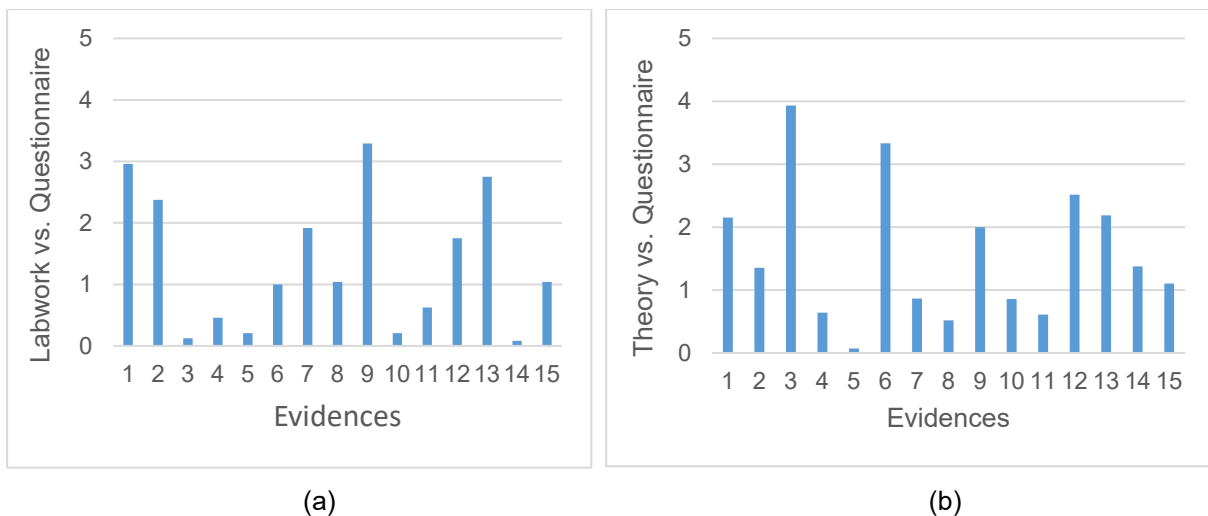


Figure 7. Comparison per evidence between questionnaire and: (a) labwork, (b) theory marks.

#### 4 CONCLUSIONS

This paper proposes a methodology to assess the generic competence regarding the technology and technical skills, named “Specific Instrumental” according to the list of main competences developed by the Polytechnic University of Valencia (UPV), in subjects within the first year of two Masters’ degrees (corresponding to Level 3). This methodology is based on checklist questionnaires that also include open questions, which have been adopted as evaluation tool to detect the degree of identification, utility and adequacy of the advanced tools (software and specific devices) by the students. In this line, the questionnaire intends to rate the handling of these tools and the criterion to select these in an efficient way to solve engineering problems.

Two questionnaires have been designed. The first one addresses the Matlab’s computer sessions through questions about the potentialities of the software and its adequacy to particular engineering

problems in front of other specialised software. The second one assesses the instrumental lab sessions and its questions encompass technical concepts of the speeder and the gearbox. Both questionnaires have been designed to cover the learning outcomes through the indicators and descriptors of the rubric developed by UPV. The authors considered to take the mark of the labwork as the most adequate way to evaluate the indicator 2 (handling advanced tools), hence the correlation between the competence and this mark is forced.

The results show that there is a certain correlation between the competence under study and the passing of the subject. The technology skills acquired during the labwork sessions are revealed important to prepare the exams according to the significant trend observed between the competence rate and the theory and global marks. Nevertheless, the observed correlation is not strong enough to assign to the competence the mark of the subject, concluding that an independent assessment tool is required to evaluate the specific instrumental competence. Moreover, the open questions have given more specific information about the technical skills acquired by the students than the checklist test, leading to a rethinking of the questionnaire design for upcoming courses. It has also been evident the need to test this assessment tool in more subjects to have more data that would allow to check whether the trends obtained during this course are representative or not. In any case, the proposed tool seems to be interesting and appropriate for the evaluation of this generic competence.

## ACKNOWLEDGEMENTS

The authors acknowledge the financial contribution by the Universitat Politècnica de València through the project PIME/2018/DPTO. IMM.

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