Applying Recommendations to Align Competences, Methodology, and Assessment in Telematics, Computing, and Electronic Engineering Courses

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***Abstract*— The alignment between competences, teaching-learning methodologies, and assessment is a key element of European higher education. This paper presents the efforts carried out by six telematics, computer science and electronic engineering education teachers toward achieving this alignment in their subjects. In a joint work with pedagogues, a set of recommended actions are identified. A selection of these actions are applied and evaluated in the six subjects. The cross analysis of the results indicates that the actions allow students to better understand the methodologies and assessments planned for the subjects, facilitate (self-) regulation, and increase students' involvement in the subjects.**

***Index Terms*— Alignment, competences, engineering education, methodologies.**

I. Introduction

THE work done in recent years by the Spanish Higher Education system in order to meet the demands from the European Higher Education Area (EHEA from now on) has led to reflections on the institutional and academic organization of the centres, the curriculum and syllabus – understood as the learning programme – and the subjects as working cores within that programme. From these work, new questions arise that lead to new reformulations so as to gradually improve the approach of the training based on competences [1].

These new challenges are fundamentally in line with getting a methodology that allows the training of the competences proposed in the subjects. In order to design activities and tasks that result enabling, meaningful and attractive to our students and, so as to achieve a greater consistency in general, there is the need to reflect about the subjects'assessment system. This reflection brings a complex and costly task that focuses on understanding, from the training, academic and organizational perspectives, the importance of the alignment between the three key elements: competences, methodology and assessment. Holistically understanding a subject, or a set of these, depends on the nature of the subjects themselves. Our case stands in the context of the IEEE disciplines, and more concretely in the scope of Telecommunications Engineering, Computer Science and Electronic Technology. These subjects have evolved and have been articulated following the EHEA guidelines [2], [3] (and other regulations towards the formulation of the Degree programmes) with the fundamental objective that the students develop a set of general and particular competences along all subjects.

The Spanish universities have already done several efforts to adapt their studies to EHEA. The Teaching Quality and Innovation Support Unit of the Polytechnic School (USQUID-ESUP) of the Universitat Pompeu Fabra has carried out various studies on this line that raised information about the profile of the freshmen [4], which, in turn, has helped in the design and assessment of the University Introduction Course [5], [6]. If we observe the scenario from a national perspective, we realize that the efforts in this direction are also important and varied. These actions include a careful design of the new degrees [7], the study of the organization of subjects in modules [8], the provision of tools to design syllabuses and training activities [9]–[11], the implementation of teaching-learning active methodologies [12], [13] based on collaborative learning techniques [14]–[17], [26]–[30], on projects [18], [19], or on problems [20], and the formative and summative assessment of the student more and more oriented to competences [21]–[23].

In this paper, we present the experience carried out in different subjects within the IEEE scope where we have implemented different mechanisms to enhance, promote and entrench the relationship between competences, teaching methodologies and assessment systems ($C* M* A$ from now on). The presented work is the result of a wider project within the Fund Program "Analyses and Studies", call of 2009, entitled "Aliena ME, Competence Development in ICT Engineering Degrees: Aligning Teaching and Learning Methodologies with Assessment" [24] and coordinated by USQUID-ESUP. The working team included 5 pedagogues and 17 teachers of the engineering scope from 7 Spanish universities

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(in alphabetical order: Universitat Autònoma de Barcelona, Universidad de Cádiz, Universidad Carlos III de Madrid, Universitat Pompeu Fabra, Universitat Ramon Llull, Universidad de Sevilla and Universidad de Valladolid). The project's objectives were: (1) analyse the consistency of methodology and assessment with the competences to be achieved in each one of the subjects under study; (2) select those recommended actions that teachers consider optimal and feasible for its implementation in the corresponding subjects, providing a consistent and reliable process both in terms of implementation, monitoring and assessment; (3) apply such recommendations and evaluate their impact in terms of teachers' and learners' satisfaction. This work allowed the creation of 12 recommended actions of different nature and complexity [25]. In this article we present 6 cases where a selection of these recommendations has been applied during the 2009-2010 year.

The rest of the article is organized as follows. Section II explains the context and the methodology carried out in the development of this work. More concretely, we detail the recommended actions identified in the project Alinea ME, the subjects where these have been applied, and the methodology used to apply them. Section III describes the development of the recommendations'implementation as well as the obtained results. Finally, section IV discusses the conclusions derived from the study.

II. Working Methodology and Recommendations for the C∗ M∗ A Alignment

The study presented here is essentially organized and developed from a qualitative perspective, in combination with the detection of quantitative trends, in order to accommodate the objectives and objects of study, where the importance and influence of the context is remarkable [26]. The ultimate goal of the research is to obtain the required know-how from which to establish some action-oriented guidelines. In other words, to improve the alignment processes between competences-methodologies-assessment (C∗ M∗ A).

As said in Latorre, Del Rincón and Arnal (2005:92) [27], this is about a study aimed at educational practices. This type of analyses are essentially designed to *contribute to solving problems or provide guidelines for the actions*, therefore the final outcomes are the decisions and recommended actions rather than contributing to the creation of knowledge or theories. The studies developed from this perspective do not have their own methodology in the sense that they are based on methodologies mostly used in empirical-analytic and constructivist guidelines. In this regard, the research is hence based on a mixed approach.

According to the definition of Van Dalen (1990) [28] we can state that this is a study of interrelationships. Specifically it is an analysis of *multiple cases* that are explored both from the descriptive and interpretative perspectives [29]. And this essentially allows a more rigorous approach to the reality of the case studies that has allowed to establish proposals both at general level, aimed at improving the C*M*A alignment, and at individual level, address the idiosyncrasies of each case.

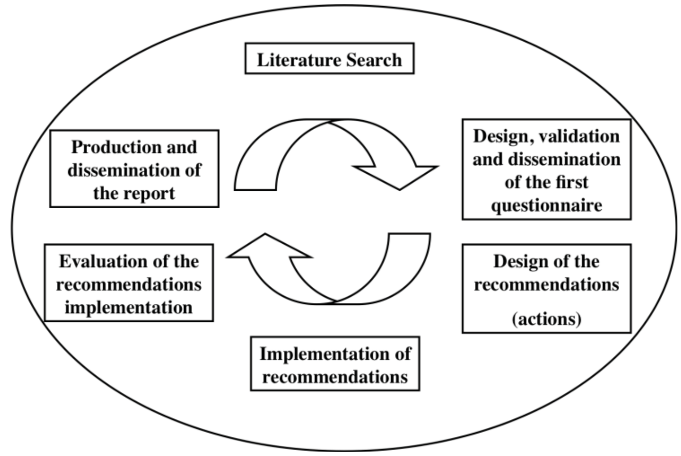

Fig. 1. Work methodology.

A. Work Methodology

The methodology followed throughout the process – including the contextual analysis, design of recommended actions, the corresponding implementation, and the assessment – was based on a feedback approach between the teachers involved, pedagogues and the project coordination. Given the mixed approach of the research, the data collection instruments contained items of different nature. These instruments were applied with software tools to systemize the process. Fig. 1 depicts a schematic graph showing the methodology followed from the initial to the final stages.

There are six basic phases. The first one focuses on the *literature search* to contextualize the starting point and to envision "where one wants to go." The second phase *designs, validates and disseminates the first questionnaire* that reflects all the elements about "what, how, why, which and when" the involved teachers work and assess. The third phase includes the *design of the recommendations* aimed at optimizing the starting situation in terms of consistency between C*M*A by agreement with the involved teachers.

Afterwards, the fourth phase *applies the recommendations* to the corresponding cases, collecting evidences in terms of satisfaction and success both from the faculty and students. The fifth phase focuses on the *evaluation of the recommendations' implementation*: data collection, analysis of results and conclusion drawing. Finally, the *production and dissemination of the report* allows the analysis of each subject context and leads to a reflection on the possible improvement in order to optimize the starting situation.

In the evaluation phase, apart from analysing the results for each case,we have done an overall assessment of the actions that have been common to more than one case. This crossed analysis has allowed us to obtain a contrasted view of the recommendations' effects.

B. Recommendations

The design of the recommendations arises from a process that begins with the collection of information about the key features of the subjects – competences, methodology, assessment system, etc. – in order to diagnose possible weaknesses

TABLE I
DESCRIPTION OF THE INVOLVED SUBJECTS

Subject	Telematics Applications III (AT-III)	Telematics Complements II (CT-II)	Computer Architecture and Technology II (ETC-II)	Systems Architecture (AS)	Web Engineering (IWeb)	Telematics Systems on Education and Medicine (STEM)
Type of subject, year, credits	Quarterly subject, 3rd year, 4,5 ECTS, Compulsory	Quarterly subject,5th year, 6LRU credits, Optional	Quarterly subject, 1st year,7.5 LRU credits, Core	Quarterly subject, 2nd year, 6 ECTS, Compulsory	Quarterly subject,4th year, 4.5 LRU credits, Optional	Master quarterly subject, 5 ECTS (specialization on "Telematics Systems")
Degree where it is taught, University and enrolled students	Telecommunications Engineering-Telematics (Old programme) U. PompeuFabra 34 students	Telecommunications Engineering(Old programme) U. de Valladolid 23 students	IT EngineeringSpecialization on Management (Old programme) U. deSevilla 80 students	Degrees on Telematics, Communications Systems andMultimedia systems. U. Carlos III de Madrid 40 students	Computer Engineering U. de Cádiz 15 students	TIC Research Master U. de Valladolid 12 students
Concerning the competences to work in the subject	**Specific:** design and development of telematics applications with Servlets and JSPs by accessing databases, capacity to recognize and justify the factors involved in the selection of technologies and products for the design and development of Web applications. **Transversal**: oral and written communication, planning and time management, teamwork, capacity to apply knowledge to practice.	**Specific:** management of networked information systems, technologies for integrated management of networked information systems: managing Internet, Web-based management. **Transversal**: reasoning skills, concept relationship, analysis and synthesis, teamwork, organization and planning, oral and written communication in the field of telecommunications and electronics.	**Specific**: related to the cognitive aspects: knowledge and understanding of the design and use of digital systems. And related to procedural aspects: know-how, design, building and use digital systems. **Transversal**: capacity for analysis and synthesis, problem solving, teamwork, capacity to apply theory to practice.	**Specific**: C programming of nontrivial applications, industrial management tools **Transversal**: Teamwork, self-learning ability.	**Specific**: methods, techniques and tools for Web application development, implementation of the complete cycle of a Web application **Transversal:** planning and organizational skills, teamwork, motivation for quality and independent learning.	**Research skills** critical attitude, writing and communication, innovative proposals, etc. Within the specific context of the intersection in Telematics and the application domains (Education and Medicine).
Developed activities developed in the subject	This course combines conducting a project where the students, in groups of three, must design and develop a Web application, with individual activities to resolve short practice assignments and analyse various Web technologies and cases, all in a collaborative manner by use of wikis, glossaries and discussion forums.	The students carried out group activities in the lab aimed at the implementation, in a controlled scenario, of network management applications based on some of the technologies discussed in the first part of the course. Each group was asked to produce a final report and an oral presentation.	Development of 4 team activities applying cooperative learning; each one divided into 4 tasks related to planning, assimilation of fundamental concepts, practical implementation and presentation of the work on a poster format. The teacher provides continuous feedback using the electronic group portfolio.	This subject uses a strategy of active learning with continuous assessment. Each session consists of previous and in-class activities. The first half of the course the practices are conducted in pairs and in the second half working teams of 4 or 5 people are created.	During the first part of the course, the students develop a series of works in a wiki-based collaborative environment, focused on learning new methods and development environments, while in the second part of the course the teams develop a Web project at all phases of the cycle life of software engineering.	It is based on case studies and using multiple collaborative techniques. The students analyse real scenarios, related to basic bibliography as well as challenges for R&D&I. The evaluation is formative and includes all the generated artefacts as peer review and self-evaluation. The course is based on a Wiki platform and external tools both individual and collaborative.

(as well as strengths). As of this analysis, the approach of the recommendations is more contextualized to the cases so these can be analysed and evaluated by the teachers that will apply them. The second step that is carried out is to share the produced recommendations and provides pace for discussion about their viability and consistency. This step took place in a meeting with the entire Alinea ME project team where the members used group discussion dynamics involving not only teachers in the engineering field but also professionals of pedagogy. In addition to the analysis of recommendations, reflections emerged around how these processes could be carried out, what could be the drawbacks that teachers could face, and also the strengths of each recommendation. Following there is a brief summary of the guidelines or core aspects that are covered by all recommendations.

In general terms, the recommendations can be classified in 3 groups concerning: planning actions that have the greatest impact before the subject starts; planning and development activities that have the greatest impact during the development of the subject; and, finally,assessment actions that can be performed at the beginning, during or at the end of the training process.

1) Regarding the planning actions that have an impact before the course starts:
    a) Compilation of “Best Practices” carried out in the area itself (even in related subjects) that are based on the alignment of C*M*A.
    b) Strengthen, promote and establish communication channels with the teaching and research staff responsible of the subjects (especially considering the subjects that require certain competences related to others and vice-versa) to work cooperatively in the planning of competences (level acquisition by subject-course) as well as strategies to foster and evaluate such competences. This recommendation could involve a second action focused on reducing, levelling and distributing competences logically and consistently over the subject or degree (this can be done with “groups” of subjects). This way, the competence levels can be detailed and this actually helps facilitating their management in the design of the syllabuses.
    c) Taking care of terminology. For example, talking about continuous assessment where labs, classroom activities, seminars, etc., have a weight in the evaluation, one should not use the word “exam”, which has always stood for unique and final evaluation. It would be more appropriate to call it “test” or “individual practice with an evaluative nature”.
    d) Make the C*M*A alignment explicit in the syllabus and present it to students so they become aware of “what, how and why”they will work and will be evaluated.
2) As of recommendations that have a major impact during the development of the subject (although they assume a previous planning and organization work):
    a) Virtuous Triangle: The student workload is a clear indicator that allows the teacher to see how much they work in alignment(both within and between subjects), so teachers should make an effort to determine the degree-intensity of each competence measuring the work required by an “average” student to carry out the proposed activities. From this point the teacher can regulate and adjust the methodological approach and assessment of each case. Figure 2 shows this “virtuous triangle” where all lines are discontinuous to emphasize the constant feedback and the permeability of the process.
    b) Choosing, as much as possible, the work methodology according to the competence to work, and minimizing the effects of the resource limitations, group size, etc.
    c) Combine different methodological techniques and strategies to make competence training broader so it reaches all students.
    d) Verify that the projects are a substantial part of the C*M*A design. This practice is very common on engineering studies and, therefore, it is important to ensure that its approach-design responds consistently to the alignment sought.
3) And finally, those recommendations that refer to the processes that assess the competences.
    a) Inquire about the level of competence of the students at the beginning of the subject. This way the teacher collects evidence from the starting point of the group and students become aware of their level of competence.
    b) Include in the assessment process those transversal competences listed in the syllabuses. To do so, one can design small tools to collect evidence on their evaluation [30]–[32].
    c) Design the assessment of the subject as a learning task-process and present it this way to the students.

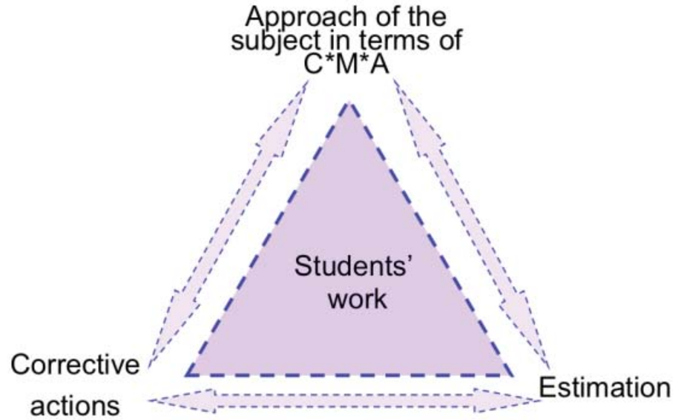

Fig. 2. Virtuous triangle.

As observed, within the general framework of the proposed recommendations we find a different depth range, understanding such depth as complexity and viability depending on the subject and its idiosyncratic characteristics. Six subjects have applied a sub-set of these recommendations in the 2009-2010 year. This work focuses on the recommendations 1.d, 2.a, 2.c and 3.a, as these are the most common in the subjects and hence those that allow us to draw crossed conclusions using the results obtained within each subject. In the following section we provide a more explicit detail on the

TABLE II

OVERVIEW OF THE RECOMMENDATIONS IMPLEMENTATION AND EVALUATION PROCESSES

Recommendation	Implementation	Evaluation
1.d Make the C*M*E alignment explicit in the teaching plans and present it to students so they become aware of "what, how and why" they will work and will be evaluated n = 2 subjects (AT-III/ ETC-II)	- Include elements in the syllabus that show the C*M*A alignment and make them explicit in the presentation of the plan to the students.	• Ask students about their perception regarding the usefulness of knowing the intentional relationship between the three elements.
2.a Virtuous Triangle n = 4 subjects (AT-III/ CT-II/ IWeb/ STEM)	• Collection of data about the student's dedication in scheduled activities. • All students taking part in the activities. • Per-activity systematization of feedback regarding the dedication	• Use instruments either specific for this purpose or by means of the subject global evaluation process.
2.c Combine different methodological techniques and strategies to make competence training broader so it reaches all students n = 4 subjects (AS/ AT-III/ ETC-II/ STEM)	• Reflect on which strategies and techniques can better meet the objectives of the subject and the scheduled activities. -Raise several task-instrument/strategy relationships, combining them so as to cover several interpersonal competences or learning styles.	• Ask the students about their own assessment on combining multiple strategies and techniques for the subject evaluation. • The teacher gathers observations and notes about it.
3.a Inquire about the level of competence of the students at the beginning of the subject. In this way the teacher collects evidence from the starting point of the group and students become aware of their level of competence n = 4 subjects (AS/ AT-III/ ETC-II/ STEM)	• Introduce to the students the list of competences so they can assess their development level in each case, using rubrics, real examples or professional contexts, etc.	• Ask questions in the opinion questionnaire at the end of the subject. • Provide students with an open questions questionnaire the last day of the subject. • Gather comments and informal feedback made by students.

implementation process. Before, we provide some details about the subjects participating in the study.

C. Subjects

Table I shows the description of the subjects involved in the study, including details relating to the type of subject, the competences posed in each one and the proposed activities.

As seen in the table, the contextual features of the subjects (degree, year, number of students) are varied and represent a sample of the diversity of subjects in IEEE fields (Telematics, IT, Electronics) where we need to work towards the C*M*A alignment. In particular, the subjects that take part of the study are core, compulsory and optional subjects, ranging from 1st to 5th year and a Masters course. The number of students enrolled in each course varies from small groups of students (12-15) to large groups (80). The specific competences worked in the subjects depend on their particular specific areas, with a (partial) match in the case of AT-III and iWeb. Differently, there is a greater convergence in the case of transversal subjects. In particular, the most common competences are those related to teamwork, planning and time organization, or written and oral communication.

The characteristics of each subject have been important in the study when choosing the recommended actions to implement in each subject (see section III.A), including the preparation of the activities or works proposed to the students.

The last row of Table I provides the description of these proposed activities, including: the development of application following a project-based learning methodology, the preparation of technical reports, participation in discussions about the selection of appropriate technologies for case studies through asynchronous interaction tools (wikis, forums), oral presentations, lab sessions,analysis of information sources, and review of other students work. Additional details about the proposed works in the subjects can be found in [24].

III. DEVELOPMENT AND RESULTS

This third section contains the most significant elements of implementation and evaluation of the recommendations, as well as the results obtained. To make it easier to read and given the amount of data collected, the information is again synthesized into tables.

A. Implementation of Recommendations

As mentioned before, although the implemented recommendations were common to several subjects, the process may have been different given the characteristics of each particular case. This is why Table II shows a summary relating each recommendation with the matching elements during its implementation onto the subjects, together with the evaluation process that was carried out.

Thus, the table reflects the fundamental elements of both the implementation process (instrumentation, resources, timing, etc.) and its evaluation impact. As it is noted, it mainly relates to the perceived satisfaction and usefulness from the students' perspective, complemented with the teachers observations and reviews. Given the nature of the study, and even if the same recommendations are used, the results in the different subjects do not necessarily have to match. Context components and idiosyncrasies of the subjects themselves may prove to be conditioning factors.

TABLE III

CROSSED AND PER-SUBJECT RESULTS OF THE RECOMMENDATIONS IMPLEMENTATION

Recommendation	Crossed Results	Per-Subject Results
1.d Make the C*M*A alignment explicit in the teaching plans and present it to students so they become aware of "what, how and why" they will work and will be evaluated n = 2 subjects (AT-III/ ETC-II)	• At the end of course the general feeling is that students have perceived a better "rationale" of the proposed activities.	• Comments like the following one are observed in several cases: "*The teaching plan has been quite helpful to understand the approach of the subject, to better organize the works and projects and the time dedicated to them*." [AT-III] • After the development of the subject, the teacher appreciates the recommendation observing that students are more focused on the teaching-learning process. [ETC-II]
2.a Virtuous triangle n = 4 subjects (AT-III/ CT-II/ IWeb/ STEM)	• It facilitates and encourages student self-regulation in terms of dedication, not only in the subject concerned, but also reverts on remaining subjects. • The feedback allows corrections (teacher estimation-real student dedication) so as to improve the development of the subject. • A positive impact on the competences of task planning and in study time organization (making explicit the intention to continue working this in future subjects-years).	• The students suggest that the analysis of time/dedication is helpful for other courses or subjects, but not so much for the on-going one. One student stated that there should be a transversal subject to learn how to make these estimates and assess competencies in a subject that includes working on a project (planning/organization). [IWeb] • Measuring the workload has helped the students to better organize their working time within the subject. [CT-II] • The teacher has noticed that the regulations regarding the dedication time have led to an increase in the quality of the works and projects carried out by students compared to previous years. [AT-III] • The fact of knowing the average load of the working group is considered useful or very useful to students. [CT-II] • 83% of students who responded to the evaluation questionnaire claim to have perceived some improvement (understanding this as rebalancing) in terms of the workload of the course. Also, 66.7% said that it was helpful to better manage their time. [STEM]
2.c Combine different methodological techniques and strategies to make competence training broader so it reaches all students n = 4 subjects (AS/ AT-III/ ETC-II/ STEM)	• Increase of the student's involvement and greater motivation towards the proposed activities. • The teachers can evaluate the potential and constraints of each competence training technique. • Risk of feeling a greater workload as the number of techniques to collect learning evidences increases.	• Teacher satisfaction with the result obtained from the combination of methodology and evaluation techniques applied. [AT-III] • About 70% of students who completed the questionnaire provided positive comments on this regard (especially because of the motivational component that this new way of working represents). Occasionally,comments regarding the inability of spending all the time they should were also collected. [AT-III] • The students state to be more involved in the subject and that they have learned to coordinate with the teammates after getting used to the new way of working. [ETC-II] • The teacher assessments through observations and data from student performance are positive. [STEM] • Working using a variety of techniques/strategies allows to value the strengths and weaknesses of each one of them, especially those related to team-work. [AS]
3.a Inquire about the level of competence of the students at the beginning of the subject. In this way the teacher collects evidence from the starting point of the group and students become aware of their level of competence n = 4 subjects (AS/ AT-III/ ETC-II/ STEM)	• It is useful to inquire about their competence at different points along the course in order to locate themselves in the right scope, assess their progress and reflect on important aspects of the competences covered	• The teacher considers that a high percentage of students do not understand what competences really mean and, in most cases, they sound distant to them. In any case, making them aware of what they know before and after results satisfactory in most cases. [ETC-II] • 83% of students bring positive comments in this regard emphasizing motivation and reflection on their progress throughout the subject. [AT-III] • The repetition of self-assessment of competences in three stages along the subject is considered as the most valuable. The teacher used the last session to discuss some of the "hard" competences as those relating to "multidisciplinary" work, the "critical sense" or "societal and ethical implications". [STEM] • The students agree that "*The fact of reflecting at this level makes it clear what to be expected from us and the potential progress made on the basis of each one of the objectives established in the subject.*" [AS]

B. Results

Table III outlines the main results for the assessments and observations gathered during the process of implementation of the recommendations in the six subjects. In certain cases one can observe that the particular results differ between subjects. However, overall, the crossed outcomes show some trends indicating that the implemented actions manage to locate the students within the subjects and the corresponding methodological approach and evaluation. This results into a more (self-) regulated training and a greater involvement of the students.

IV. Conclusion

The work presented in this paper has been possible thanks to the joint reflection of teachers in the area of Telematics Engineering, Computer Science and Electronics and of pedagogical experts, who have debated, discussed and agreed upon actions to improve the alignment of competences, teaching-learning methodologies and assessment strategies raised in subjects of the engineering fields involved. The generation of recommended actions of diverse nature has allowed each teacher to adopt some of them according to criteria such as relevance, suitability to their context/subject as well as considering the feasibility and the available time vs. required time to implement the recommendation.

Among the instruments provided to collect evidence on the impact of the implementation of recommendations from the learner's perspective (especially in terms of satisfaction), different lessons learnt arise depending on the recommendation made. In the case of recommendations that focus on making explicit the perception of the C*M*A alignment and comparing the previous competence levels to those acquired during the subject, the results indicate that these actions allow students to locate themselves within the subject, to understand the methodological approaches as well as to evaluate their own progress and reflect on important aspects of the competences addressed. On the other hand, actively estimating the students' workload in order to identify corrective actions in the C*M*A approach results in providing a positive impact on the actual planning of courses and overall onto students. Finally, in the subjects under study we can see that the actions regarding the combination of different methodological techniques have a positive effect on the motivation and involvement of the students.

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