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The Challenge of Developing and Assessing Transversal Competences in Higher Education Engineering Courses*

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Current higher education is based on a competence development approach including generic competences for the integral development of students. Degrees have been designed based on this paradigm centered on lifelong learning, self-regulated learning strategies and active methodologies in which the student is the core of the formative process, aiming at contributing to develop the key competence learning to learn. In the present paper, strategies for generic competences development and evaluation are discussed in the context of engineering and technical courses and degrees. Challenges in competence assessment as well as alignment of formative assessment, methodologies and learning outcomes are discussed based on a series of experiences. Experience evidence that competence development requires designing activities oriented towards competence development, in which learning outcomes and assessment procedures are clearly defined. The alignment of these three elements is the key for competence development since succeeding in a course by achieving the defined learning outcomes implies succeeding in the acquisition of the generic competences planned. Through the paper it is also discussed that competence evaluation is a challenge for university teachers, for which they will need to be formed and trained, and provided with institutional support.

Keywords: generic competences; transversal competencies; active methodologies; competence evaluation; engineering; technical courses

1. Introduction

Higher education holds the responsibility of educating professionals able to conduct changes in society, which indeed constitutes a major challenge. In the last years, higher education has experienced a whole re-thinking of the process, not so centered on content or knowledge, but on a competence-based approach in which significant focus is placed on transversal or generic competences [1]. In this context, university lecturers must play a new role adapted to present society, being capable of guiding the integral development of students. Higher Education Institutions are committed to implement degrees based in this new paradigm for student's education, based on lifelong learning, prioritizing self-regulated learning strategies and activities in which the student is the core of the formative process [2]. In line with this, curricula have been designed in the last years to leave room for all the components that contribute to education, and this includes competencies beyond a particular discipline, i.e., transdisciplinary competences. This shift of perspective focused on learning rather than teaching, emphases three main aspects: the students as responsible subjects of their educational process; the quality of teaching and learning, and the mutual agreement about aims and contributions in a shared responsibility [3]. All agents have been involved in the process: employers, public and private institutions, present and future students, teachers, and administrations.

In Europe, changes in higher education have been driven by the creation of the European Space of Higher Education, moving teaching to this student-centered approach which determines the whole teaching-learning process. This model focuses on employability as one important goal of the educational process and designs a strategy to monitor it through specific and generic competences that the student must develop [3]. Although the model is centered in the student, this new paradigm requires new competences not only on the students but also lecturers, who are called to acquire competences making them capable of guiding the educational process. Apart from advanced knowledge in languages or information and communication technologies (ICT), lecturers must develop capabilities for effectively dealing with groups as well as teamwork strategies, to be able to guide methodological approaches close to real contexts such as project, cases, or challenge-based ones. They must combine theorical and practical knowledge with reflection and analysis of the teaching practice, inside and outside the teaching room [4]. Active methodologies are considered the basis for competence development. Through this paper it is discussed that learning activities must be oriented towards competence acquisition. This approach may imply working in complex environments,

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which demands not only skills, knowledge, awareness and strategies, but also engagement and personal commitment [5, 6]. On the other hand, it is evidenced that competence evaluation is a true challenge for university teachers, for which they will need to be formed and trained and provided with proper institutional support.

2. Objectives

After some years of implementation of this competence-focused approach, generic competences development and evaluation continues to be a challenge for university lecturers, despite the efforts devoted by them and their institutions. The present paper aims to examine some practical aspects of this competence approach, and discuss the challenges being currently faced by higher education staff for generic competence development and assessment. Examples of alignment of learning outcomes, methodologies and formative assessment procedures are provided and discussed based on a series of experiences in engineering and technical courses, with the aim of providing practical information which could serve higher education academic staff to be applied in their courses.

3. Discussion

3.1 Generic Competences Development and Assessment in Engineering Courses. The Challenge

3.1.1 Learning to Learn, Key and Generic Competences in STEM Courses

Technical subjects are defined as courses devoted to a practical study among which engineering, technology or design are found. STEM (Science, Technology, Engineering and Mathematics) courses and degrees are linked to a set of specific competences characteristic of each degree; in addition, current curricula strongly rely on the development of key and generic competencies. Key competences for lifelong learning are those which all individuals need for personal fulfilment and development, active citizenship, social inclusion, and employment [7], and include: (1) communication in the mother tongue, (2) communication in a foreign language, (3) mathematical competences and basic competence in science and technology, (4) digital competence, (5) learning to learn, (6) social and civic competences, (7) sense of initiative and entrepreneurship, and (8) cultural awareness and expression. Learning to learn stands at the top of the key competences and influences all the rest. It is defined as the ability to pursue and persist in learning, to organize one's own learning, including through effective management of time and information, both individually and in groups. This competence includes awareness of one's learning process and needs, identifying available opportunities, and the ability to overcome obstacles to learn successfully. Key competences are all considered important and many of them overlap and interlock. Competences based on language, literacy, numeracy and in ICT are an essential foundation for learning and "learning to learn" supports all learning activities. Generic competences such as critical thinking, creativity, initiative, problem solving, risk assessment, decision taking, and constructive management of feelings play a role in all eight key competences [7].

Competences are a combination of knowledge, skills, and attitudes appropriate to the context. Generic competences are characterized by being integrative, transferable, interdependent, and multifunctional. They have also been defined as evaluable, for which their need of being decomposed in learning outcomes to give credit to the level of achievement has also been claimed [8]. The acquisition of transversal competences is progressive, so that the learning process deals with the development and evolution on the students' learning mode. Students learn and improve in the way they are able to apply the acquired knowledge to new situations, integrate attitudes and principles, and incorporate methodologies and techniques when confronting new situations [9]. Therefore, competences cannot be isolated from the learning process. They are complex and integrative, they require the ability to mobilize previous learnings in specific moments, in an appropriate and inter-related manner [10]. Student evolve in their acquisition of competences as they go through their studies (undergraduate, postgraduate, PhD), for which it is necessary to distinguish different times at which special attention needs to be paid to their development and acquisition and, eventually, their evaluation. Different levels of domain are to be defined for each of these periods. Hence, competences evaluation requires the definition of levels of domain, as well as indicators and evidences to perform the assessment [9].

3.1.2 Challenges in Generic Competence Evaluation

Evaluation is a critical point in technical and professional education. It gives credit on the quality of the formative process, and students, institutions and employers must rely on it. It can be diagnostic, summative, and formative; the latter having acquired an outstanding role in current teaching-learning approaches. Formative assessment allows to close the circle between the actual performance and the desired one, serving the learning process. Thus, the student-centered approach must be based in the alignment of three axes: active methodolo-

gies, formative assessment, and learning outcomes [6].

Competences are job related descriptions of an action, behavior or outcome that should be demonstrated in individual's performance. They refer to person's underlying characteristics and qualities that lead to an effective/superior performance. In addition, competency can be more than the observed performance since competency can come up differently in different type of contexts [1]. It has been already said that generic competences need to be evaluable; however, if competences are the result of a complex know-how that is used differently in different contexts, their evaluation is, at best, a complex task.

Competence evaluation is a major challenge for university teachers and institutions. In a certain way, some may be even sceptic and believe nothing has changed or needs to be changed. The question could be: does this new approach really contribute to better develop generic competences as compared to previous ones? At this point, it needs to be recalled that the concept of competence is not new, since competences were also developed in previous curricula and previous graduates were competent. In fact, generic and key competences have always been part of higher education curricula, but they have been present in a different manner. An important point mentioned by Chur [3], is that key competences are implicitly contained in learning since in order to actively participate in courses as well as to succeed in doing their autonomous work, students need strategies of self-directed learning (focusing attention, communication and teamwork skills, or time management). These competences concern self-regulation and include knowledge, self-reflection, and action.

Nevertheless, the present approach encourages a methodological change by giving a new focus in which the goal deliberately attempts to promote a more holistic integral development of the student. Therefore, there is a need to define how contents are to be learnt, so that through the learning process previously defined competences are developed. The answer to this question leads to planification, methodology and evaluation, which must be formative and serve the learning process.

As said, learning in complex environments requires trained staff, since skills knowledge and strategies are needed; but still more important, it demands engagement and personal commitment [5]. According to Villa and Poblete [9], there are more weaknesses in how competences are evaluated in present curricula than in how these are developed. Some teachers and lecturers manifest their worries about finding adequate evidence which support the acquisition of a transversal competence [11]. In fact, making an explicit statement of what it means to be competent at given levels of learning requires specifying the learning outcomes associated to each competence [12]. To assess a competence, the expected learning outcomes and the level of domain must be clearly defined [13, 14]. This principle is very important from the operational point of view since when a competence is formulated, the teacher must think of the evidences which help evaluate the acquisition of such competence. Specific learning outcomes must be defined to link degree of achievement of competences with indicators and evidences, at different levels of domain. This can be achieved by rubrics, which must help not only teachers but also students, favoring a common language and the understanding of the expected learning outcomes [9].

However, assessing a complex performance is not easy, even if a good rubric is designed and used [11]. In addition, isolating a complex "know how" is rather difficult, despite designing or adapting a specific activity. On the other hand, the debate on whether the assessment of competencies separately is a must or not has been previously raised [11]. Indeed, many of the activities proposed as new had been already used in the past to assess students' performance, without the need for separating or isolating learning outcomes contributing to generic competences from the rest of the work. A basic example is that assignments were expected to be delivered on time in any case, and they needed to be well written and well communicated. Generic competences concern self-regulation and include knowledge, self-reflection, and action [1]. Therefore, although teachers are being asked to score generic competences, one point to be discussed is whether there is a real need for scoring a competence to ensure its development and acquisition. In effect, it is not the fact of evaluating a competence but the methodological approach itself that implies competence development. On the other hand, when giving a separate mark to a transversal or key competence, there is a potential risk of not considering the competence performance when globally qualifying the work. To our mind, the key might be in pointing at the difference between evaluating and rating. We would say that it is possible to implicitly evaluate a competence in the global performance of a task, since it has an impact on the expected learning outcome, without necessarily isolating it from global assessment and provide a specific mark to its acquisition.

3.1.3 Methodologies for Generic Competence Development in Engineering and Technical Higher Education Courses

Competence development must place the focus on

methodologies, which must be active and contribute to significant learning. In addition, methodologies must be aligned with formative assessment, thus having an impact on learning outcomes. Technical courses and degrees are particularly labor oriented and characterize by a high practical load. They are methodological and learning has traditionally required active participation, from problem solving to project-based approaches [15, 16]. To be significant, the learning process requires self-regulation, cooperation, communication, use of ICT, active participation, among other characteristics. Methodologies are the key of the change and there is no single methodology to be used, but a series of different ones that can be successfully applied. The selection of one or other implies considering several factors such as the level of domain, the capacity of a methodology to promote significant learning, student self-regulation, the number of students that can be guided simultaneously, or the number of hours that the activity requires.

Active methodologies refer to instructional methods which engage students in the learning process and involves something more than passive listening [17]. They comprise a wide range of techniques ranging from the simplest to the most complex. These can be incorporated in a class as sporadic activities or can be used for radically redesigning the entire course [18]. This includes a wide variety of methodologies such as: participative magistral lessons, problem solving, technical readings, case studies, project-based learning, challenge-based learning, oral presentations, reports writing, ethical discussion forums, lab practices, computer practices, seminars, tutorials or visits and field practices. All these methodologies are useful and currently applied to develop transversal competences in technical courses in engineering degrees and other related areas. Some of them have been traditionally used for a long time and continue to be valuable methodologies; it is the case of lab and computer practical sessions and reports writing, problem solving, participative magistral lessons, technical readings, and tutorials. These are characterized by being applicable to a significant number of students simultaneously, for which they can be used when group size is big. Others have been regularly applied to technical courses and degrees more recently, but they have become very common, such as oral presentations, ethical or environmental debates or seminars [19, 20]. Management of the group in these situations is more time consuming, and some might not be adequate for large groups. It is usual in these cases to recommend these activities to reduced size groups. Finally, other participative methodologies have generalized more recently; this is the case of flipped classroom approach and project-based or challenge-based learning [21, 22]

Regarding the flipped classroom approach, it has gained importance at the university level, and specifically in the scientific and engineering context [23]. In general terms it consists of switching what it is normally done in the classroom and what is usually done as homework. Some authors refer to the use of videos or interactive materials as the base of this approach [24]; however, a wider definition includes any material worked at home before the lecture, or even any assignment performed by students in the classroom prior to teacher explanation or doubts solving. According to Fulton [25] some of the advantages of flipped classroom include: ''students move at their own pace; doing assignment in class gives teachers better insight into student difficulties and learning styles; teachers can more easily customize and update the curriculum; classroom time can be used more effectively and creatively; increased levels of student achievement are reported; interest and engagement is improved; learning theory supports the new approaches; or, the use of technology is flexible and appropriate for 21st century learning''. Specifically, in the case of science, technology, and mathematics education, Freeman-Herreid and Schiler [26] surveyed more than 15,000 science instructors who identified some additional advantages such as more time available to spend with students on authentic research, students get more time working with scientific equipment only available in the classroom context, and students are more actively involved in the learning process.

As for project-based learning [27] or challenge-based learning [28] approaches, they are applied in real or simulated contexts which allow the students to successfully develop professional and transversal competences. These strategies are more time-consuming for student and teacher, and usually take a whole semester or an academic year to develop the project. Project and challenge-based learning approaches provide significant learning and the development of a series of transversal and professional competences such as critical thinking, teamwork, problem solving or decision taking. It mobilizes various resources to be able to make decisions and interact with the other agents involved; students drive their own learning through inquiry and work collaboratively and create projects or face challenges that require a deep applied knowledge, in a particular context.

Development of professional and transversal competences in engineering and related studies has been increasingly linked to participative methodologies. In order to evidence this trend, a literature retrieval of the last 20 years was performed by

using the keywords engineering, (active) methodologies and generic competences. Additionally, the methodologies project-based and challenge-based learning were specifically included in the literature search. Papers were retrieved from the scientific database ScienceDirect (www.sciencedirect.com) and results summarized in Fig. 1. Results evidenced a remarkable increase in the amount of published papers exploring the application of active methodologies to develop generic competences in engineering contexts. Furthermore, the literature retrieval also evidenced the interest in exploring these approaches to develop professional and transversal competences close to real contexts, as deduced from the increase in papers referring to project and challenge-based learning methodologies. Nevertheless, in spite of this methodologies being increasingly proposed in higher education contexts, it has been recently discussed that they are often misapplied or only applied in theory [17]. This evidences that shifting from a teacher-based approach to a student-centered approach in which competences are an important part of the learning process is not being an easy matter, for which sharing real examples and experiences could be of help.

3.2 Examples of Applying Active Methodologies in Technical Courses to Develop Generic Competences

In this section, the authors present a set of examples of their own experiences in using active approaches for the development and assessment of transversal competences. All the experiences presented have been applied in engineering and technical courses such as Process Engineering, Unit Operations, Mass Transport Phenomena, Food and Biotechnological Processes, Statistics, Algebra and Mathematics Analysis, as part of the curricula of degrees: Agricultural Engineering, Food Engineering, Biotechnology, Architecture and Data Science.

3.2.1 Description of the Experiences Developed and Methodologies Used

Experiences are summarized in Table 1 where the following information is presented in columns: **activity, design and methodology** (short description of the activity)**, group size** (size of the group or groups in which the activity has been put in practice and implemented)**, assessment of the activity and scoring** (how it is assessed and contributes to the course mark)**, generic competences developed** (to which competences this activity contributes)**, level of domain** (1–3) and **main outcomes**.

The main outcomes column summarizes the results of applying each experience to one or more groups, particularly focusing on transversal competences development. Results claimed are based on data collected through different means, as explained next. Teacher perspective and assessment has been gathered through systematized observation and registration (lecturer notes or diaries), or the use of specifically-designed rubrics; as for students' opinion, interviews, questionnaires, and surveys on teaching performance and methodology adequacy have been used. Table 1 summarizes a collection of experiences applied to different courses and degrees in different contexts, for which rubrics, questionnaires and surveys do not coincide for all the experiences shown. It is not the purpose of the present paper to deepen into each of them; nevertheless, some rubrics and questionnaires are presented in the Appendices section as

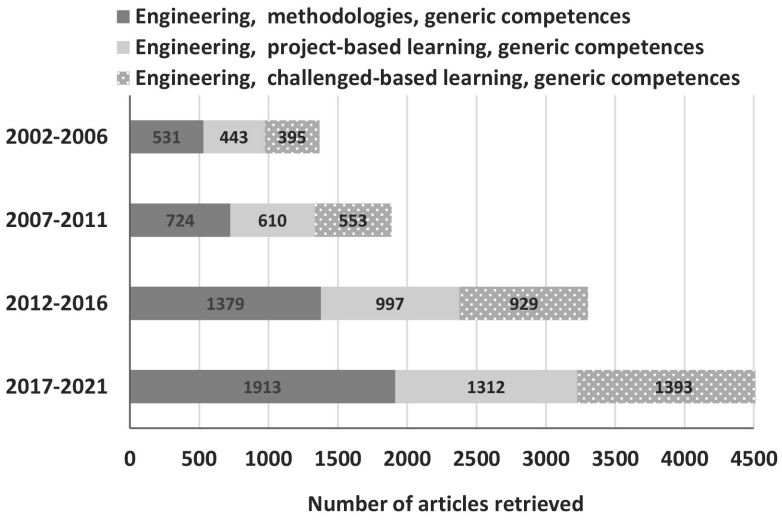

Fig. 1. Number of papers dealing with generic competence development in engineering through the use of active methodologies, project-based, and challenge-based approaches, in the last 20 years (retrieved from www.sciencedirect.com).

an example of the evaluation tools being used. The Appendices section also includes a more detailed description for selected activities. A more detailed description of some of these activities can be found in [23, 29–32]

The activities summarized in Table 1 have been classified into different categories: forums and debates, online tests and exams, technical texts or papers reading, course projects and flipped classroom, according to the methodology used. Activities design and methodologies used in the different courses and degrees are varied, as it can be deduced from the description section.

3.2.2 Main Outcomes and Overall Recommendations

According to the set of experiences presented here, different semester/year usually implies applying different methodologies or at least adapting them to a different context and student profile. Among the examples given, active methodologies applied in first years (1st and 2nd) include formative assessment activities such as online texts and exams, reading and discussion of adapted (simplified) technical texts or papers, course projects on lab and computer lab reports, or delivering an oral presentation to their classmates. In contrast, methodologies used in the last years of the degrees (4th) are more demanding and require a more in-depth competence work and self-regulation strategies; among them: reading and discussion of original scientific papers, course projects on preparing scientific posters or participating in a simulated congress (paper, poster and virtual presentation) or completing a statistics field study.

As for the number of students participating in each activity, our experience has evidenced that similar active methodologies can be applied to groups from 15, to 25 or even up to 80 or 90 students, without having a significant impact on the results (i.e., on competences outcomes). Many of the activities described (debates, tests, papers reading and discussion and different course projects) have been simultaneously applied to small and big size groups with comparable results. Of course, working with big-size groups is more time-consuming for the lecturer, but still complex activities such as debates or guided course projects can also be effectively implemented in big groups. To our mind, some strategies to succeed in big groups include planning group tutorials to solve individually raised questions, providing general tips or guidance according to previous years' experience or using co-, peer- or self-evaluation strategies.

As for competence development and acquisition, the authors experience together with the evidences gathered through several years, proved that the activities applied have served the students develop transversal and professional competences. As indicated, this has been assessed through surveys and rubrics in which both students and lecturers have participated. As for competence evaluation, our experience suggests that effectively participating in each activity implies competence acquisition and development, as long as the methodologies applied and activities developed have been specifically designed for competence development purposes. Hence, it is to be said that there is no need for giving a separated mark to competence acquisition, if indeed it contributes to global performance and, accordingly, to the global mark. In the results shown in Table 1, this can be deduced from the assessment of the activity and grading column where it is mentioned in several occasions that learning and competence practice is inherent to the activity, or that evaluation considers effective participation in the activity.

Finally, as for the competences these active methodologies have helped develop in the courses and degrees where they have been applied, the following ones have been identified by lecturers and students, as extracted from the surveys and questionnaires used: understanding and integration, ethical and environmental responsibility, critical thinking, awareness of contemporary issues, problem analysis and solving, permanent learning, practical thinking and implementation, time management and planning, communication in foreign language, teamwork and leadership, data management, effective (written and oral) communication, ethical and environmental responsibility, ICT competences.

3.3 Challenges in Competence Development Due to COVID-19 Pandemic

Recently, the whole word has faced the still ongoing COVID-19 pandemic and its impact on heath, economics, society, and, to a significant extent, on education. Among main challenges being faced because of COVID-19 situation, the following ones were initially discussed: shifting from face-to-face to online classes, changes in assessment and evaluation methods, mental health of students and lecturers, changes in universities support services, international students' issues, and travel restrictions [33].

University teachers and students are familiar with online delivery mode since at university, online activities are usually combined with face-to-face ones, contributing both to learning and formative evaluation of students. In fact, faculty members usually get training to use their institutions online learning platforms. However, the pandemic drove an unexpected change to courses fully

Table 1. Experiences for transversal competences development in higher education technical courses. Columns summarize critical aspects such as the type of activity, number of students involved, generic competences being developed, assessment methods and main outcomes. Level of domain 1 is undergraduate 1st and 2nd year; 2 undergraduate 3rd and 4th year and 3 is postgraduate

Activity developed		Design and methodology	Number of students Year and semester	Assessment of the activity and grading	Generic competences developed	Level of domain	Main outcomes
Forums and debates	***1. Debate on environmental issues using online video resources***	Students answer a preliminary questionnaire and visualize a video on a controversial environmental issue. Then debate is generated, students must take part and fill again the questionnaire, which is then delivered through learning platform.	A group of 80 and a group of 25 students 4th year 7th semester	Learning and competence work is implicit in the activity. Value is given to participation and delivery of questionnaire.	Understanding and integration; Ethical and environmental responsibility; Critical thinking, Awareness of contemporary issues.	2	Motivation and interest for the topic of study. Students get motivated by the topic and relate the course content with contemporary issues. Oral and debate abilities are developed.
Online tests and exams through learning platform	***2. Online test and exams through learning platform, in the classroom (Formative assessment activities during magistral participative lectures)***	Students are invited to answer online tests on theoretical and practical questions (calculations, relate, deduce) during lectures, as part of magistral participative sessions. Teacher provides feedback, which is also automatically provided online.	A group of 0 and a group of 25 students 2nd year 4th semester	Learning and competence work is inherent to the activity for which mark is not particularly given.	Understanding and integration; problem solving; Permanent learning; Practical thinking and implementation.	1	Students put in practice their knowledge and learn from it and the feedback received (formative assessment). In the classroom it promotes participation and the use of ICT.
	3. Online test and exams with feedback for self-assessment and self-regulated learning out of the classroom (Online Formative assessment activities)	Students are invited to answer online tests on theoretical and practical questions (calculations, relate, deduce) which provide automatic online feedback.	A group of 80 and a group of 25 students 4th year 4th semester	No score is given to this test, it helps prepare the final test and develop the competences needed to success on it.	Understanding and integration; problem solving; Permanent learning; Practical thinking and implementation.	2	Formative assessment which serves the learning process. It promotes self-regulation of learning. It promotes the use of ICT.
Technical texts or papers reading	***4. Reading and discussion of technical texts adapted to the students' level***	Reading of adapted technical documents introducing new concepts and answering questions. The teacher answers questions and students may use computers, tablets, or mobile phones. Student may ask their classmates, working collaboratively in pairs or small groups.	A group of 90 and a group of 25 2nd year 4th semester	Effective participation, appropriateness of answer to questionnaire and delivery on due time are considered.	Understanding and integration; Permanent learning; Practical thinking and implementation; Time management and planning; Problem analysis and solving.	1	Students are responsible for their own learning developing self-regulated strategies. The teacher facilitates the materials and guides them through the activity. Different resources are used: written document, digital and human resources (teacher and classmates).
	5. Reading and discussion of original (not adapted) scientific papers	Scientific papers selected by the lecturer are analyzed and discussed by students. Students may use computers, tablets, or mobile phones to solve questions. Students work collaboratively in pairs or small groups. Teacher usually does not participate until the end of the activity.	A group of 80 and a group of 25 students 4th year 4th semester	Effective participation, appropriateness of answer to questionnaire and delivery on due time are considered.	Understanding and integration; Permanent learning; Practical thinking and implementation; Time management and planning; Problem analysis and solving; communication in foreign language.	2–3	It contributes to the key competence learning to learn. Students are responsible for their own learning developing self-regulated strategies and different resources are used in an autonomous and collaborative manner: written document, digital and human resources (teacher and classmates).
Course project	***6. Course project based on a set of lab and computer lab reports writing and discussion: reports are presented as an opportunity to learn and improve performance along the course using rubrics and formative assessment***	Students work in small groups to prepare their reports on lab and computer sessions following the teachers' instructions. Rubrics and correction criteria are facilitated, increasing the level of command required along the semester. Feedback is given to contribute to formative assessment.	A group of 90 and a group of 25 2nd year 4th semester	Reports are evaluated based on rubrics with correction criteria. Students are given a mark and feedback to progressively improve their performance.	Teamwork and leadership; Effective (written) communication; Permanent learning; Practical thinking and implementation; Time management and planning; Problem analysis and solving.	1	The key competence learning to learn is involved in the process since students learn to identify the expected learning outcomes, plan the time needed to perform the work in due time and write the reports, and develop teamwork abilities.
	7. Course project on preparing a scientific poster	Students work in small groups (select a topic, database search for reliable information, reading and selecting relevant information, poster design and building). Students present and explain the poster to their classmates. Professor provides guidance along the whole process. Guidelines, deadlines, and rubrics are provided at the beginning.	A group of 15 students 1st year 2nd semester	Learning and competence work is implicit in the activity. Work is supervised every week so that all milestones are covered. Oral presentation and posters are assessed with rubrics (teacher and co-evaluation).	Teamwork, Understanding and integration; Permanent learning; Practical thinking and implementation; Time management and planning; Data management, Effective communication.	1	Students gain ability to set a work plan and stick to it, analyze and process scientific information. They are responsible for their own learning process developing self-regulated. Students also improve communication skills and critical thinking thanks to the co-evaluation process.

Table 1. (*continued*)

Activity developed		Design and methodology	Number of students Year and semester	Assessment of the activity and grading	Generic competences developed	Level of domain	Main outcomes
Course project (*continued*)	***8. Development of an academic project to be presented in a congress simulated context***	Students work in small groups to prepare a course project to be presented in a simulated context (scientific congress simulation). Written (paper), poster and virtual presentation are delivered and assessed based on facilitated rubrics (teachers, co- and self-evaluation is used). Guidelines, deadlines, and rubrics of assessment are provided at the beginning of the process.	A group of 80 and a group of 25 students 4th year 4th semester	Assessment is based on rubrics given at the beginning of the activity. Teachers-, co- and self-evaluation is used. A mark is given to the written paper, poster and virtual presentation (video) of the poster.	Teamwork and leadership; Effective (written and oral) communication; Communication in foreign language; Understanding and integration; Analysis and problem solving; Permanent learning; Awareness on contemporary issues; Ethical and environmental responsibility; Time management and planning; ICT competences.	2–3	Specially motivating activity which contributes to transversal and professional competences of a scientific profile. Students guide their own learning process, make decisions on it, and plan their times. They develop teamwork abilities and interpersonal skills, assess their own work and their peers. Develop autonomous and self-regulated abilities.
	9. Statistics field study: planning and conducting a statistical study from data gathering to results interpretation and conclusions	Students work in small groups to conduct all steps of a statistics study (set a topic, fix the target population, build questionnaire, send it to the sample, gather data, data processing, get results, draw conclusions). Teacher provides guidance along the process. A written report and oral presentation are delivered. Guidelines, deadlines, and rubrics are provided at the beginning.	A group of 15 students 1st year 1st semester	Continuous work is supervised every week so that all milestones are covered. This part is not graded. Oral presentation and report are assessed with rubrics and a mark is given.	Teamwork, Understanding and integration; Permanent learning; Practical thinking and implementation; Time management and planning; Awareness on contemporary issues; Problem analysis and solving; Data management; Effective communication (written and oral)	1	This is a very motivating activity that allows the students to complete a research on a topic of their interest, apply statistical concepts in a real situation, work with databases, get started in scientific research, work in teams, set a work plan and stick to it, develop autonomous and self-regulated abilities and improve communication skills.
Flipped classroom	***10. Ted Talks discussion: selecting, explaining, and debating a Ted Talk related to Mathematics in a foreign language***	Students must browse and select a Ted Talk related to Mathematics (individually). An oral presentation is delivered including introduction and contextualization, interest of the talk, visualization of the talk, conclusions, and questions to debate. Guidelines, deadlines, and rubrics are provided at the beginning.	A group of 15 students 1st year 2nd semester	Learning and competence work is implicit in the activity. Participation in debates and presentation of the activity are assessed with rubrics.	Understanding and integration; Permanent learning; Time management and planning; communication in foreign language; Awareness on contemporary issues.	1	This activity allows the students to work transversal competences, integrate knowledge by relating Maths with other fields (music, sports, environment, art, business, etc), and improve communication skills in a foreign language.

delivered online [34], with little or no time for transition. In this context, some teachers felt not well prepared for facing online teaching, mainly when lectures used to be face-to-face, thus not feeling comfortable when delivering lectures "to a screen". Others were overwhelmed by preparing new materials and adapting their subjects in a time-less context.

As for students, although they were expected to adapt easily to online learning, they also suffered the consequences of poor adaptation or coordination since the situation did not have the opportunity to be planned. On the other hand, they experienced an increased workload in a context in which they were not used to learn (home with virtual contact with classmates). In addition, students are particularly concerned about their education as well as by their performance and evaluation, and the impact this will have in their development. Institutions and academic staff worked hard for planning the following year based on different scenarios, so that courses were taught mainly online and in a hybrid mode in the academic year 20–21. In the subsequent year, 21–22, most institutions were back to face-to face teaching.

Development and evaluation of generic competences were also affected by pandemic driven changes. In the first moments, many activities could not be developed since they had been defined for face-to-face contexts and were not appropriate for online methods. Then, activities and methodologies needed to be re-defined and shifted to an online or hybrid mode to properly develop the generic competences defined in the degrees and assess them based on defined learning outcomes. These had an impact not only on methodologies, but also on evaluation processes which needed to be adapted. These implied a significant workload increase for university lecturers. At present, the situation has improved but still some hybrid teaching is present for which activities need new description and planification. In addition, changes in students' behavior and performance because of pandemic-driven new studying habits are being

noticed. This will need to be analyzed and thoroughly considered in order to be capable of applying active methodologies and designing activities oriented towards competence development.

4. Conclusion

The present paper has analyzed the current situation regarding generic and key competence development in the context of technical and engineering courses and degrees. It has been discussed that it is the process itself that ensures competence development, for which methodologies are more relevant than assessment. Yet, evaluation is a critical point since it gives credit on the quality of the formative process, which means generic competencies need to be considered in the evaluation process. Nevertheless, assessing generic competences does not necessarily imply to separate them from the whole performance, neither assigning a mark to them.

The authors own experiences have been gathered and detailed to provide a framework to discuss on what activities can be used, how this can be adapted to different levels and group sizes, and how evaluation can be accomplished. Through this, it is concluded that methodologies need to be specifically planned to develop transdisciplinary competences, considering each particular context and the different levels of domain. This, combined with well-designed assessment methods, leads to an adequate development of generic and key competences, since succeeding in a course and achieving previously defined learning outcomes implies succeeding in transversal competences acquisition.

References

1. TRACE (Transparent Competences in Europe). Overview of European Competency Frameworks, http://www.menon.org/wp-content/uploads/2012/11/9.-TRACE-Overview-of-EU-competencyframeworks1.pdf, 2012.
2. M. C. Barron, Docencia universitaria y competencias didácticas, *Perfiles educativos*, **31**(125), pp. 76–87, 2009.
3. D. Chur, Developing Key Competences in Higher Education, *Heidelberg: Winter Verlag*, pp. 54–74, 2011.
4. P. Perrenoud, Diez nuevas competencias para enseñar, Editorial Grao, 2th edn, Barcelona, 2007.
5. X. Kolmos, M. L. Du, P. Dahmsm and P. Qvist, Development for Change to Problem Based Learning, *International Journal of Engineering Education*, **24**(4), pp. 772–782, 2008.
6. A. E. Guerrero-Roldán and I. Noguera, A model for aligning assessment with competences and learning activities in online courses, *The Internet and Higher Education*, **38**, pp. 36–46, 2018.
7. Recommendation of the European Parliament and of the Council of 18 December 2006 on Key Competences for Lifelong Learning (2006/962/EC), Official Journal of the European Union L 394/13.
8. Proyecto competencias transversales UPV, https://www.upv.es/entidades/ICE/info/Proyecto_Institucional_CT.pdf.
9. A. Villa and M. Poblete, Evaluación de competencias genéricas: principios, oportunidades y limitaciones. Assessment of Generic Competencies: Principles, Opportunities and Limitations, *Bordón*, **63**(1), pp. 147–170, 2011.
10. L. Jiménez Reina, Métodos de evaluación de las competencias transversales. Assessment methods of generic/transversal competences, *Educación Médica*, **16**(1), pp. 17–23, 2015.
11. L. Seguí and M. Galiana, Some experiences on developing and evaluating transversal competences in higher education, *Proceedings of INTED2018*, pp. 7090–7098, 2018.
12. Education and Training 2020 Work programme Thematic Working Group 'Assessment of Key Competences' Literature review, Glossary and examples. EUROPEAN COMMISSION. Directorate-General for Education and Culture. http://ec.europa.eu/dgs/education_culture/ repository/education/policy/school/doc/keyreview_en.pdf, 2012.
13. Wolf, Competence-based assessment, In J. Raven and J. Stephenson, *Competence in the Learning Society*, New York: Peter Lang, 2021.
14. W. Harlen, Criteria for evaluating systems for student assessment, *Studies in Educational Evaluation*, **33**(1), pp. 15–28, 2007.
15. I. W. Hung, A. C. Choi and J. S. Chan, An integrated problem-based learning model for engineering education, *International Journal of Engineering Education*, **19**(5), pp. 734–737, 2003.
16. B. Galand, M. Frenay and Raucent, Effectiveness of problem-based learning in engineering education: a comparative study on three levels of knowledge structure, *International Journal of Engineering Education*, **28**(4), p. 939, 2012.
17. E. Crisol-Moya, M. A. Romero-López and M. J. Caurcel-Cara, Active Methodologies in Higher Education: Perception and Opinion as Evaluated by Professors and Their Students in the Teaching-Learning Process, *Frontiers in Psychology*, **11**(1703), pp. 1–10, 2020.
18. M. Hernández-de-Menéndez, A. Vallejo Guevara and J. C. Tudón Martínez, Active learning in engineering education. A review of fundamentals, best practices and experiences, *International Journal on Interactive Design and Manufacturing*, **13**, pp. 909–922, 2019.
19. A. Rai, Role of Communication Skills Laboratory in Empowering the Communicative Competence in Engineering Students, *International Journal of Educational Research and Technology*, **5**, pp. 1–4, 2014.
20. R. Ramli, Technology enhanced learning: Fostering cooperative learning through the integration of online communication as part of teaching and learning experience, *World Academy of Science, Engineering and Technology*, **69**, pp. 611–614, 2010.
21. A. Karabulut-Ilgu, N. Jaramillo and C. T. Jahren, A systematic review of research on the flipped learning method in engineering education, *British Journal of Education Technology*, **49**(3), pp. 398–411, 2018.
22. P. Guo, N. Saab, L. S. Post and W. Admiraal, A review of project-based learning in higher education: Student outcomes and measures, *International Journal of Educational Research*, **102**, p. 101586, 2020.
23. M. Galiana and L. Seguí, Implementing flipped classroom in the school of architecture, *Proceedings of ICERI2016*, pp. 8197–8201, 2016.
24. J. L. Bishop and M. A. Verleger, The flipped classroom: A survey of the research, *SEE National Conference*, 2013.
25. K. Fulton, Upside down and inside out: Flip your classroom to improve student learning, *Learning & Leading with Technology*, **39**(8), pp. 12–17, 2012.

26. C. Freeman and N. A. Schiller, Case Studies and the Flipped Classroom, *Journal of College Science Teaching*, **42**, pp. 62–66, 2013.
27. S. Bell, Project-Based Learning for the 21st Century: Skills for the Future, *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, **83**(2), pp. 39–43, 2010.
28. W. B. Gaskins, J. Johnson, C. Maltbie and A. Kukreti, Changing the Learning Environment in the College of Engineering and Applied Science Using Challenge Based Learning, *International Journal of Engineering Pedagogy*, **5**(1), 2015.
29. M. Galiana and L. Seguí, A strategy to develop emotional intelligence in the classroom, *Proceedings of ICERI2014*, pp. 2340–1095, 2014.
30. L. Seguí and A. Heredia, Congress simulation for the development of scientific competences in undergraduate students, *Proceedings of ICERI2014*, pp. 3540–3547, 2014.
31. M. Galiana and L. Seguí, Ted talks applied to education of architecture students, *Proceedings of ICERI2015*, pp. 1348–1353, 2015.
32. M. Galiana and L. Seguí, Monitoring transversal competences in technical courses at an undergraduate level, *Proceedings of ICERI2019*, pp. 3946–3952, 2019.
33. P. Sahu, Closure of Universities Due to Coronavirus Disease 2019 (COVID-19): Impact on Education and Mental Health of Students and Academic Staff, *Cureus*, **12**(4), 2020.
34. V. Gewin, Five tips for moving teaching online as COVID-19 takes hold, *Nature*, **580**(7802), pp. 295–296, 2020.

Appendices

Table A1. Example of rubric used by lecturers to assess the generic competence: time management

ITEM	Limited	Developing	Proficient	Advanced
Uses time effectively (25%)	Does not recognize the reality of time constraints or take action to use available time efficiently	Barely uses time efficiently and completes work within given time constraints	Uses time efficiently and completes work within given time constraints	Prioritizes tasks, recognizes time constraints, estimates time to completion, and avoids distraction while meeting deadlines and using time effectively
Establishes a schedule for completing work (25%)	Does not establish a schedule for completing the work	Sometimes establishes a schedule for completing the work	Most of the times establishes a schedule for completing the work	Always establishes a schedule for completing the work
Stays on schedule (25%)	Does not stay on schedule	Sometimes stays on schedule	Most of the times stays on schedule	Always stays on schedule
Format and content of the activities (25%)	Delivers the activity with serious mistakes in content and format	Delivers the activity with some mistakes in content and format	Delivers the activity with almost any mistake in content and format	Delivers the activity without any mistake in content and format

Table A2. Example of rubric used by lecturers to assess the generic competence: oral communication skills

ITEM	Limited	Developing	Proficient	Advanced
Clarity to explain contents / organization	Explanation of contents is confusing, disconnected, and disorganized	Explanation of contents is difficult to follow but understandable in general	Explanation of contents is almost entirely clear and organized	Explanation of contents is made in a clear way, totally organized and it is easy to follow
Diction (vocalization, vocabulary, and volume)	Poor diction and vocalization. The speech is not clear, lacks proper vocabulary and the volume is low	Orator shows a good diction and vocalization, but lacks proper vocabulary and shows low volume	Orator shows a good diction and vocalization, good volume but can improve the use of a wider range of vocabulary	Orator shows a good diction and vocalization, good volume and uses a wide and proper range of vocabulary
Pacing and voice inflection	Oral presentation is either too quick or too slow and student uses a monotone voice	Oral presentation is made in bursts and student show some level of inflection throughout the delivery	Oral presentation is patterned, and the use of inflection is satisfactory, but does not consistently use a fluid speech	Good use of drama and time interval. The speech is fluid and maintains the interest of the audience
Body language and eye contact	Student does not move or use descriptive gestures and does not hold eye contact with the audience	Student uses very little movements and descriptive gestures and displays minimal eye contact with the audience	Student uses movements and descriptive gestures that help understand the presentation and displays regular eye contact with the audience	Student uses fluid movements and descriptive gestures to enhance the presentation and holds attention of the audience with the use of direct eye contact

Table A3. Examples of 1 to 5 Likert questions included in questionnaires and surveys answered by students to evaluate their perception on the impact of the activity on the acquisition of transversal competences

Questions:
- This activity has drawn my attention over new aspects of Architecture
- I consider the topics of the Ted Talks chosen by my classmates were motivational and inspiring for me
- This activity has allowed me to improve my English communication skills
- This activity has made me reflect upon ethical issues
- This activity has strengthened my social awareness
- The activity allowed me to improve my abilities for searching information in specialized data bases
- This activity allowed me to improve my written communication skills
- I believe the poster format is useful to improve synthesis capacity
- I believe the rubric provided is a helpful tool for adapting my work to the expected outcomes
- I believe this activity has helped me in self-regulating my own learning
- I consider this activity allowed me to develop professional-related skills
- My overall satisfaction level with this activity is high

Answers:
1. Strongly disagree
2. Rather disagree
3. Neither agree nor disagree
4. Rather agree
4. Strongly agree

Table A4. Detailed description of the activity "Statistics Field Study"

Course: Fundamentals of Statistics, 1st year, 1st semester

Number of students: 30 **Group size**: 3–4 students/group

Duration: 2 months

Summary: The aim of this activity was to develop a project which help students to understand, integrate and apply the contents studied along the course. Each group was asked to propose a research topic of the students' interest, to analyze the relationship among two or more variables. Some examples were: sports and academic performance, e-commerce and population type, psychological consequences of COVID and population type). Students were asked to develop the project based on the scientific method, so that they followed the following steps and handed in deliverables according to defined deadlines:

- Initial hypothesis, based on an observation
- Definition of the variables to be studied (dependent and independent)
- Description of the nature of the variables (qualitative (attribute/ordinal), quantitative (continuous/discrete)
- Definition of the population object of study; selection of a sample of at least 40 individuals
- Design of a questionnaire to gather information (in English). Students are then provided a guide with a set of important points/good practices to develop a good questionnaire.
- Teacher revises the questionnaire, which is finally upload and launched/sent to sample.
- Data obtained through questionnaires is introduced in Excel to be analyzed and studied with statistical tools (selected by students as they consider more appropriate)
- Results are obtained and conclusions drawn
- Initial hypothesis is accepted or rejected
- Students perform a literature search to compare their results with already published works
- Students present their results to their classmates in an oral presentation session

Competences developed: Many competences were involved in the learning process when developing this activity. To cite some: team work, planning and time management, analysis and synthesis of information, communication in the mother tongue and in a foreign language, sense of initiative and entrepreneurship, awareness of contemporary problems.

Table A5. Detailed description of the activity "Ted Talks discussion"

Course: Structural mechanics, 2st year, 2st semester; Conditioning techniques, 3th year 1st semester

Number of students: 15 **Group size**: Individually

Duration: 3 months

Summary: Students were invited to search and select a Ted Talk dealing with Architecture to be watched and discussed in class. One condition was that the Ted Talk should discuss some ethical issues or transmit ethic or environmental values. Some of the examples were: Ethics in Architecture, Social responsibility, Sustainability and Environment, Architecture aid after a natural disaster, Green spaces for more pleasant cities, Live and work in a globalized world. The activity was designed as follows:

- Each student selects and work individually on a Ted Talk of his/her interest.
- The duration of the Ted Talk should range between 10-20 minutes so that the essential message and fundamental ideas were addressed in a clear and direct way.
- The language of the Ted Talk should be English (with the possibility of Spanish captions).
- Before the Ted Talk was visualized in class, the student had to make a short speech explaining why he/she had chosen it, the values he/she wanted to transmit to the class and the issues he/she wanted to share and reflect on.
- In other to facilitate comprehension of the talk, the student had to prepare a glossary of 10 key words related to the topic of the Ted Talk and share it before the projection.

- The student had to raise questions to generate debate, which was moderated by the teacher.
- Students answered a survey to assess their experience regarding this activity and their perception on this activity contributing to competence acquisition

Competences developed: Many competences were involved in the learning process when developing this activity; to cite some: Understanding and integration, Permanent learning, Time management and planning; communication in foreign language, Awareness on contemporary issues; Ethical, professional and environmental responsibility.

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