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Teaching Using Collaborative Research Projects: Experiences with Adult Learners in Distance Education

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Abstract: This research studies the acquisition and improvement of specific cognitive, functional, and social competencies of the students enrolled in a university module in which we applied Collaborative Research Project (CRP) strategy. The module was Research Methodology for a master's degree in research in electrical engineering, electronics and industrial control given at the National Distance Education University (UNED) in Spain. This practice was applied to a research project in which the private sector was interested in. We have been aiming at increasing academia–industry interaction while promoting active learning; both are principles advocated by the European Higher Education Area (EHEA). Having applied this strategy, the module learning outcomes were evaluated following the guideline standards set by the National Agency for Quality Assessment of Universities (ANECA) of the Spanish Government. The results from this evaluation indicated that CRP, even when carried out by using distance learning, has encouraged the students' interest in both research and the module. It has also fostered collaboration between students and lecturers while increasing their degree of satisfaction. We highlight the difficulties in merging all the outcomes from the students' research as the main drawback.

Keywords: online and blended learning and teaching; online open learning environments; open education technologies; learning/teaching methodologies

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1. Introduction

The fields of intervention of the electromechanical engineer are as broad as human development itself. This is because we are dealing with a very dynamic and innovative professional sector. Social evolution itself requires the training of these professionals to be able to face an increasingly changing and diverse reality. European convergence articulates the idea of providing electromechanical engineer students with a broad repertoire of competences that enable them to successfully carry out this broad profession.

Something that characterizes societies today is the difficulty of foreseeing all these competences because they are constantly changing. Tasks faced by these future professionals require the integration of competences and not the aggregation of them in order to solve many of the complex and diverse situations that may arise in their professional lives [1].

Over the past few decades, as science and techniques have become more and more complex, there have been several initiatives intended to promote further collaboration between researchers and workers [2,3]. Thus, in the scientific professional world, some authors pointed at the need to start training of all types of professionals in collaborative research attitudes from the school [4,5]. A new formative tool appears within this context,

which develops additional competences in the students while allowing for their evaluation throughout the research process, namely Collaborative Research Project (CRP) [6]. This strategy allows the students to be in contact with state-of-the-art research while working in interdisciplinary environments and, depending on how the initial problems have been posed, offers them the possibility to work on real problems [6,7].

Collaborative Research Projects concerning teaching [5,7] have several advantages: They favour experiential learning, promote the acquisition of competences, facilitate implicit knowledge transmission, and promote connections within concepts and improve group dynamics. Concerning research, they also expand networks, increase research visibility, promote research ethics, and develop appreciation for research and knowledge. Thus, with respect to competences, CRP develops a range of them useful for both for academia and industry, specifically those of the following: [5,8]: teamwork capacity, leadership, communication skills, creativity, resilience, problem solving, research skills, new problems identification, critical thinking, and professionalism. In the particular case of distance learning, it familiarizes the students with virtual environments for group work [9]. However, some drawbacks have been pointed out concerning this practice [10]: difficulties finding appropriate partners, financial difficulties (as this methodology is expensive to run), increased faculty efforts, social laziness effect, difficulty to cover the entire syllabus, excessive time consumption, increased administrative duties, difficulties at groups outputs, and reconciliation and problems when creating homogenous groups [11].

2. Literature Review

In order to define the professional profile of an electromechanical engineer, it is necessary to resort to the University Degree in Electromechanical Engineering Royal Decree 921/1992 [12,13] (Spain) in which the official university degree in electromechanical engineering is established, and the general guidelines of the study plan to obtain it are approved. It includes the following training profile of these studies:

> *"The courses leading to the official degree of Electromechanical Engineer must provide adequate training in the theoretical bases and technologies of this Engineering".*

Therefore, it be said that an electromechanical engineer is a professional in engineering and technology in charge of improving business productivity by applying scientific and technological knowledge. As experts in efficiency and performance, they should not only work in the technical field but also analyse the financial and human sections. Although this definition of functions is true, it is mainly orientated towards the development of the electromechanical engineer within the area of manufacturing and fabrication. In our opinion, it overlooks other possible activities that can be developed by an electromechanical engineer, namely research, and this area is where we think CRP may play an interesting role.

2.1. Aims, Objectives, and Learning Outcomes

There exists general confusion between the terms' aims, objectives, and learning outcomes. Aims are lecturer-centred statements of intention, which define broadly the focus, direction, and purpose of the teaching experience [14]. Objectives, for their part, are also lecturer-centred but are more specific and detailed [15]. The Bologna Working Group on Qualifications Frameworks [16] defined learning outcomes as the following: "Statements of what a student is expected to know, understand, and/or be able to do at the end of a learning period". There is also some misconception between objectives and learning outcomes, the main reason being that objectives have been sometimes written in terms of learning outcomes [17]. In order to distinguish them, we considered that objectives are centred on the lecturer and the teaching process, while learning outcomes are focused on the student and the learning process, which are frequently observable and, thus, can be measured [18]. Nowadays, there is a general tendency to speak of learning outcomes as they are considered easier to compose and more clear and transparent than objectives [15].

2.2. Competences

Ever since various universities collectively designed the European educational structures, work has been carried out on the idea that competences are part of the curriculum. The reader must keep in mind that there is an intricate frontier between the concepts of learning outcome and competence. This is so because learning outcomes are generally expressed in terms of competences (see, for example, the Spanish Royal Decree 1393/2007 [19]).

One of the contributions of the Tuning Project [1] is to have an integrated approach for the concept of competence. This is carried out by considering the dynamic combination of professional qualities and characteristics, which allow for professional performance in various situations and contexts. Thus, it defines competence as the ability to use a combination of knowledge, skills, and attitudes in work, study, and professional contexts as well as for personal development. It divides competences into instrumental, interpersonal, and systemic competences [20,21]. Instrumental competences have a mediating function in facing tasks and developing learning, such as the ability to learn and make decisions, to organize and plan, and so on. Interpersonal skills refer to abilities of the students to interact amongst one another and with larger groups of people. They tend to facilitate and favour processes of social interaction and cooperation, such as critical and self-critical capacity or the ability to work in interdisciplinary teams, and so on. The third group of competences (systemic) permits the students to apply knowledge in practice, allows them to have an overview, to anticipate the future, and to understand the complexity of a phenomenon or a reality, for example, the ability to adapt to new situations, to learn throughout life, and similar situations. Another contribution is the classification and description of the generic and specific competences to be considered in university degrees. The generic competences are those common to any degree. That is, they are independent of the subjects: Although necessary, they are not sufficient in themselves for professional practice. Specific competences are those particular of each degree, specialization, or work profile.

An accepted definition derived from Bloom's taxonomy of learning domains [22,23] observes competences as an integrated combination of knowledge ("know"), skills ("know how to do"), and attitudes ("know how to be") (KSAs) necessary to be able to reach a certain level of capacity to perform a task [12,24]. The European Qualifications Framework for Lifelong Learning (EQF) [25], in line with the Copenhagen process technical working group (TWG), speaks of three major categories, namely knowledge (cognitive), skills, and competence (KSCs); the latter ones including responsibility and autonomy. In our research, we included meta-competencies within the social competences category, following [26].

2.3. Research Hypotheses

Based on the studies above, we considered it interesting to put to the test the conjectural improved acquisition of competences CRP comports to the students enrolled in a module in a master's degree in electromechanical engineering of a distance-learning programme. To this end, we tested the following hypotheses:

Hypothesis 1. *CRP implementation has a direct positive effect on perceived cognitive competences.*

Hypothesis 2. *CRP implementation has a direct positive effect on perceived functional competences.*

Hypothesis 3. *CRP implementation has a direct positive effect on perceived competencies and social competence.*

In addition, to try to understand the extent to which students increased their motivation for both research and their studies, we established our last hypothesis:

Hypothesis 4. *CRP implementation has a direct positive effect on student's interest in research and/or the module.*

3. Methodology

3.1. Participants

The research took place in the module research methodology in electrical, electronics and industrial control engineering of the master's degree in research in electrical engineering, electronics, and industrial control of the Higher School of Electromechanical Engineers of the National Distance Education University (UNED) in Spain. The sample of participants in this study was made up of 168 students. As per gender, 83% of the sample were male and 17% were female; the average age was 28 years. The questionnaires were carried out within the virtual campus of the course throughout April 2018 before the evaluation. The students completed the questionnaire anonymously to avoid, as far as possible, distorting their answers and to increase their honesty. Although they were given time to respond to all the items, they took an average of 15 min to complete the questionnaire. A total of 104 replied to the survey.

3.2. Research Design and Procedures

The students were provided with a real research problem described in a specifications document. They were asked to delve into the problem, propose a solution, and uphold the proposed solution (non-quantitative problem-solution research). Tasks assigned to the students included the following (Table 1): (a) the formulation and presentation of similar problems; (b) cooperative planning of research tasks; (c) obtaining relevant information from documentary and computer sources and so forth; (d) classification, organization, and interpretation of this matter; (e) writing up a final report; and, finally, (f) the presentation and discussion of the research work in the online group forums in the presence of the lecturers.

Table 1. Chronogram of the activities performed throughout the module.

Tasks	Month															
	January				February				March				April			
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Formulation and approach of problems that aroused the curiosity and interest of university students	X	X	X													
Cooperative planning of research tasks				X	X											
Obtaining relevant information from documentaries, computer sources, and so on.					X	X	X									
Classification, arrangement, and interpretation of relevant information from documentary sources							X	X	X							
Drafting of a final report									X	X	X	X				
Sharing and discussion of the research work in the class													X	X		
Conducting surveys of university students															X	X

In order to comply with the previous tasks, the students had to provide the following outputs: (a) clear determination of their research objective (for example, through brainstorming), providing evidence of their work using a portfolio; (b) an information-gathering portfolio (database, teamwork in libraries, reading-rooms, and so on); (c) evidence of the organization and analysis of the information gathered through the creation of schemes

and concept maps (presentation); (d) the final research report; and (e) the presentation and communication of the final results to colleagues (use of PowerPoint, audio-visual media, and so forth).

The groups were created randomly. Three groups competed with one another in searching for the best answer. Each group (55 students) was divided into 5 subgroups (10 students) each one with its leader. Common Group Learning (CGL) was the organizational model initially suggested for each subgroup. Under this system, the problem is divided according to the interests and expertise of the group. The group then evaluates each contribution as a whole, and the final research output provides the common view of the group. However, we observed the spontaneous apparition of group leaders who coordinated the group resulting in an organizational structure as that shown in Figure 1. Groups worked in parallel and were encouraged to compete with one another in their search for the best solution.

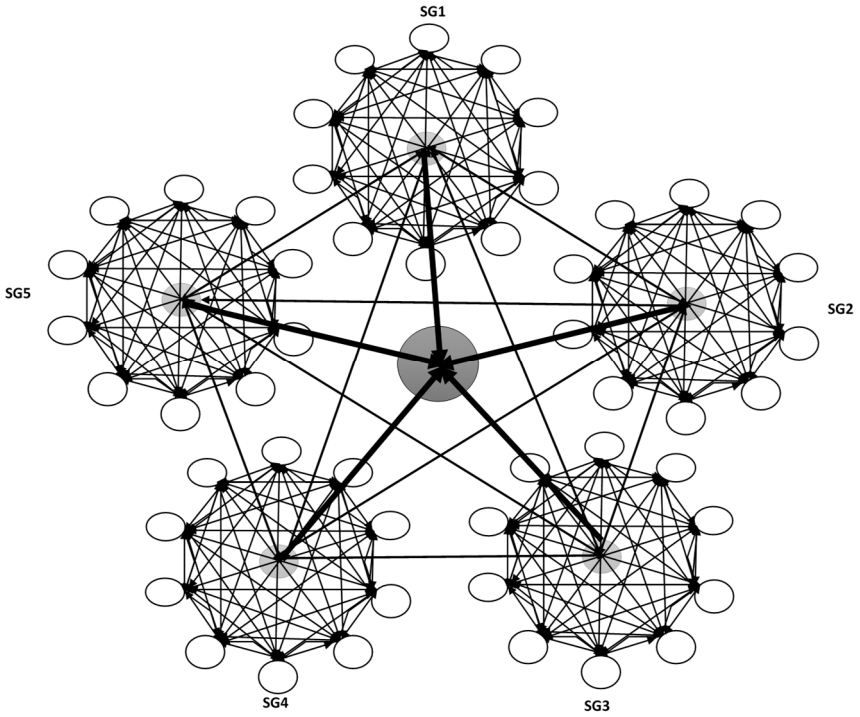

Figure 1. Diagram of the interaction of the students within one of the 3 groups and interactions within each subgroup.

At the end of the module, an examination panel of experts performed the evaluation.

This fact provided feedback to the students and encouraged them to work even harder. By using this method, we also tried to reproduce realistic situations in which the students had to hand in the results to their employers.

3.3. Measures

The students were asked to complete a survey expressing their degree of satisfaction with the learning outcomes. The survey used resulted in a Likert scale with 39 items and 5 response levels, ranging from 1 ("I did not acquire it") to 5 ("I acquired it or improved it optimally"). This scale was chosen for all variables for easy comparison between the cognitive, procedural, and generic and attitudinal competences and with other research works as it is widely used. It covers three types of competences, 11 knowledge or cognitive competences (K), 12 skills or functional competences (S), and 16 competencies or social competence (C and SC). Table 2 shows the types of competences evaluated in this research.

Table 2. Competences evaluated in the Research Methodology in Electrical, Electronics and Industrial Control Engineering course.

1. Knowledge or cognitive competences (K)
1.1 To know the basic theoretical foundations of electromechanical engineering
1.2 To understand the new trends in electromechanical engineering
1.3 To identify the main components of the evaluation model of university education based on collaborative projects
1.4 To analyse the elements which make up an evaluation report responding to criteria of utility, precision and ethics of the evaluation applied to a university context
1.5 To know the use and meaning of information gathering procedures and techniques in a research process
1.6 To know the main models of group training, development, and completion
1.7 To understand and apply appropriate methodological strategies and techniques for the resolution of research cases
1.8 To know results of applied research on more effective intervention techniques, programmes, or strategies with each type of individual
1.9 To identify the characteristics that define and profile individuals and groups in different educational contexts
1.10 To identify different parts of a research report
1.11 To know the theoretical foundations and design of resources, materials, and training programs
2. Skills or functional competences (S)
2.1 To contrast different theories of research methodologies applied to engineering
2.2 To identify the educational actions developed by the agents involved in a training process
2.3 To apply educational measurement instruments adapted to the research objectives
2.4 To design a teaching-learning process
2.5 To know how to apply research projects that promote professional development and projection towards research and teaching careers
2.6 To develop intellectual and scientific competences related to the generation of scientific knowledge
2.7 To use different resources and technological applications
2.8 To develop proposals and to develop information-gathering techniques
2.9 To design a group-training plan and to develop the training actions involved
2.10 To plan the improvement aspects of the project according to quality criteria
2.11 To evaluate research reports
2.12 To communicate results effectively
3. Competencies and social competence (C and SC)
3.1 Analysis and synthesis capacity
3.2 Reflective capacity
3.3 Systematic and global vision
3.4 Critical and analytical capacity in educational and research situations which can be evaluated
3.5 To encourage an open, flexible, and understanding attitude on the complex nature of the evaluation process
3.6 Rigour and accuracy application in the use of measurement instruments for the research and educational reality study
3.7 Diagnostic and research capacity
3.8 Decision-making capacity
3.9 Work planning, coordination, and organization
3.10 Development of a critical, positive, and plural attitude towards research as a tool for understanding and improving the educational reality
3.11 Rigour in the analysis and assessment of resources and contexts
3.12 Coordination, organization, and supervision capacity
3.13 Approach to searching for diverse documentary and bibliographic sources
3.14 Development of creativity in the design and use of resources
3.15 Assessment of distance/guided training
3.16 Motivation to encourage action and effort for the task

Note that the different types of competences are grouped according to Winterton et al. 2006 [26], who maintained a KSC structure incorporating meta-competencies within the social competences category.

3.4. Data Analysis

Quantitative data from the survey were analyzed using version 13.0 of the software Statistical Package for the Social Sciences (SPSS).

4. Results

4.1. Knowledge or Cognitive Competences

The cognitive competences in which students feel that they have acquired more proficiency are the following: "To identify different parts of a research report" (Mdn. = 4.15), "To know the roles and meanings of information-gathering procedures and techniques in a research process" (Mdn. = 3.93), and "To analyse the elements which make up an evaluation report responding to criteria of utility, precision, and ethics of the evaluation applied to the university context" (Mdn. = 3.80).

In a more specific manner, it can be stated that the competences that students consider to have acquired or optimally developed at the cognitive level (answered with a four or a five on a Likert scale) are those related to understanding the new trends in electromechanical engineering. Thus, 82% of the students answered question 1.2 of Table 2 with a four or a five. Furthermore, the key participants in this research consider it fundamental to analyse the elements that make up an evaluation report, responding to criteria of utility, precision, and ethics of the evaluation applied to the university context (77% of the students answered four or five). With this aim in mind, a code of ethics should be established which sets out the profile of action in the different educational contexts proposed in this research.

Understanding and applying appropriate techniques and methodological strategies for the resolution of educational research cases (79% of the students) are also two of the competences widely recognized by the individuals. This is why they considered it essential to develop a procedure according to methodological criteria which allows them to carry out the research and teaching tasks in any field related to the professional competences which electromechanical engineering students are provided with throughout their careers. To carry this out, it is essential to be able to identify the characteristics which define and profile individuals and groups in different educational contexts (92% of the students), as well as to identify the different aspects of a research report (95%). Finally, most students (87%) consider that they have started to recognize different theoretical foundations and can design resources, materials, and training programmes for electromechanical engineers (mainly those specialized in the electrical engineering field).

4.2. Skills or Functional Competences

Concerning the most valued procedural competences, the following stand out: "Evaluate the research report" (Mdn. = 4.00), "To communicate results effectively" (Mdn. = 3.85), and "To use different resources and technological applications" (Mdn. = 3.73) (Figure 2).

Thus, 89% of the students consider that they have completed the course by being able to identify the research and educational actions carried out by the agents involved in a research and training process. They are also able to apply research and educational measurement instruments adapted to the research aims, such as structured (closed questionnaires) and unstructured information collection tools (open interviews, content analysis, and so on). One of the most striking achievements using this methodology is that 98% of the students stated that they know how to apply research projects, which promotes their projection towards research and teaching careers. This is achieved by using different technological resources (84%) available on the UNED virtual campus.

Moreover, students consider that they have also learned the following:

- To elaborate proposals to develop techniques to obtain information (79%);
- To design a group-training plan and develop the training actions involved (80%);
- To evaluate the research report that they deliver once the course has been completed (93%);
- To transmit the results effectively according to the conclusions that each working group draws from the work process carried out through collaborative research conducted online (85%).

4.3. Competencies and Social Competence

Finally, the analysis of the competencies and social competence shows that those acquired or improved on are "Motivation to encourage action and effort for the task"

(Mdn. = 4.13), "Work planning, coordination and organization" (Mdn. = 4.11), and "Decision-making capacity" (Mdn. = 4.08) (Figure 2).

In relation to the above, the analysis and synthesis capacities together with the reflective capacity (98%) were the most favourably valued by the students once they completed the course. Collaborative work for research projects also fosters a systematic and global vision (89%) of the whole teaching-learning process, out of which the students highlight the following factors:

- Rigour and accuracy application in the use of measurement instruments for the study of educational and research reality (73%);
- Diagnostic and research capacity to elaborate material and provide the research with a theoretical context (77%);
- Development of a critical, positive, and plural attitude towards research as a tool for understanding and improving the education reality in different contexts (81%);
- Coordination, organization, and supervision capacity in the different tasks of the whole research process (75%);
- Development of creativity in the design and use of resources, both the existing ones and those elaborated by each working group (91%).

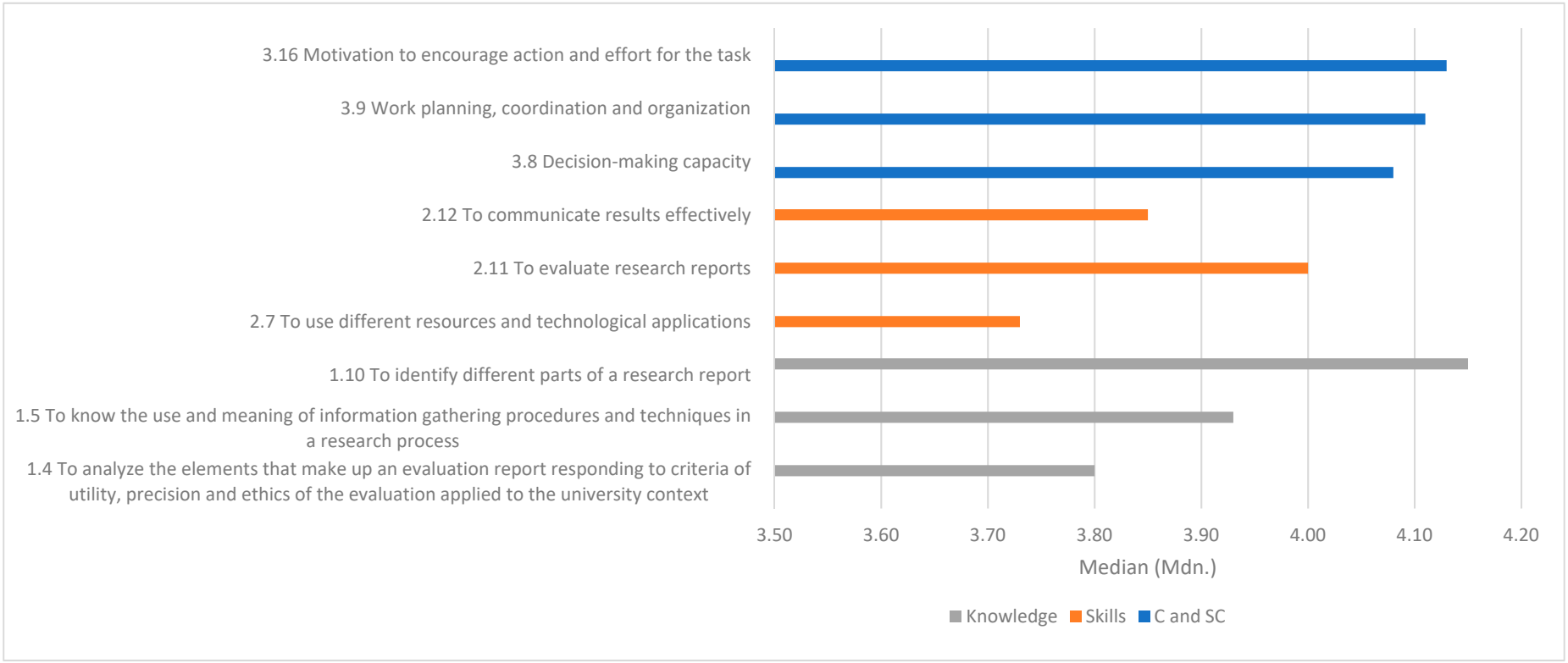

Figure 2. Most valued competences and competencies acquired by the students. C and SC stands for Competencies and Social Competence.

5. Discussion

It has been frequently reported in the scientific literature that student's commitment and achievements can strongly improve increasing their degree of active participation in classroom activities (e.g., Mead, 2017 [27]). Specifically, the results suggest benefits for CRP that are similar to previous studies. Hence, in both cases, we reported an increase in analytical thinking, understating of key concepts understanding, critical reasoning, knowledge application, management, group work capacity, networking, needs identification, communication skills, interculturality, and personal values (e.g., [5,9,28]).

Thus, in our study, CRP proved effective at providing improvements for most competences and competencies considered for this research. Other than the previous experiences, we highlight the degree of autonomy with which our students have appropriately resolved novel situations. Moreover, this methodology provides an environment in which students observe other students as reciprocal partners for both teaching and learning.

Furthermore, the interest the students showed in the module significantly increased, even when extra effort should be made when on a task (93%), thus creating an environment where effort prevails. This fact can be corroborated if we take as an indication the 250% increase in the emails lecturers received from the students with respect to the previous year. Students who failed to pass the module the previous year pointed out that the module was more interesting with the methodology applied, although more time-consuming. Finally, we can indicate that we detected an increase in the interest of the students of the module in our PhD programme than compared with the previous years.

Despite all the advantages above, CRP diluted our authority as lecturers in favour of new hierarchies created among the student community; we were almost mere spectators. Another aspect to highlight is that, in our view, not all students seem to be either suitable or comfortable with this methodology (new and proactive methodology); thus, a previous preselection process could be advisable. Moreover, there were difficulties in merging all the outcomes from the students' research in a single document. Finally, we must indicate the extra workload this methodology required of us than compared with the previous years.

Concerning the limitations/delimitations of the study, we highlight that it was performed for a public online institution with the consequent bias concerning the characteristics of the students. This fact implies difficulties in extrapolating its results for other institutions. Moreover, there is a certain geographic limitation, partially attenuated by the abovementioned online nature of the module. Finally, there are still some questions pending to be solved concerning student selection, groups size, type of organizational structure and research task selection.

Future research in different worldwide institutions would be advisable to provide a more complete view on CRP as a teaching-learning tool. This fact would also permit evolving from perceived learning results to actual learning results derived from a comprehensive sample of programs, modules, and evaluation systems. The implementation of this new methodology will require more time and practice before it is fully developed.

6. Conclusions

The results obtained show that students were very satisfied with the development of the course. This fact agrees with our perception that the cognitive, procedural, and generic and attitudinal competences were attained using the CRP strategy. Thus, regarding the first two aims, significant learning seems to have taken place, as can be observed by the quality of the work produced. However, students specifically highlighted their perception of acquisition or improvement of those competences related to teamwork. This is because they experienced what a group is in a progressive, systematic, and continuous manner; how it is formed; and how it develops and how it ends. Interpersonal communication (virtual in this case) and conflict management competences were developed as a result. These competences determine their performance in the management of the different groups in which they work with throughout their professional careers. Thus, it is worth noting their perception of an increase in their capacity to understand power relationships among

members and leadership. They also feel more capable of planning, coordinating, and organizing work. As a result, the usual "complaints" about lack of time for their academic tasks have diminished. This, up to a point, has avoided the undesirable social laziness effect, which sometimes takes place in group work. Furthermore, although this strategy sometimes requires extra financial support, particularly in the case of experimental research, this was not the case in our distance-learning methodology in which we conducted non-quantitative problem-solution research. However, as a main drawback from the practice, we should point out that a lot of extra work was required from lecturers, more so than in a normal course. As a proven rationale for the Collaborative Research Project (CRP), the implementation and usefulness results of this paper are in harmony with the ones presented in previous experiences, such as the ones provided by Dobber et al. [29], Whelan et al. [30], and Keraminiyage et al. [9], that have already proven the benefits of collaborative learning for enhancing students' research-related knowledge, skills, and attitudes under faculty guidance. This experience of innovation brings out aspects that are directly related to competence-based university education. Students' predisposition and favourable attitude towards it suggest that it should be further implemented in university contexts.

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