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Effectiveness of cooperative, collaborative, and interdisciplinary learning guided by software development in Spanish universities

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Abstract
The European Higher Education Area (EHEA) proposes to enhance active learning and student protagonism in order to improve academic performance. In this sense, different methodologies are emerging to create scenarios for self-regulation of their learning. In this study the cooperative, collaborative and interdisciplinary learning methodologies were compared in Spanish universities. The main objectives were to evaluate their effects in higher education and to explore the relationship between perceived group cooperation and self-perceived ability to work in a group, differences between educational Spanish contexts, educational methodologies and gender. To this end, a quasi-experimental design was carried out. Data analysis included the descriptive metrics, correlations and analysis of variance to evaluate the differences among pedagogical methods, their effects on cooperative learning, teamwork outcomes and gender differences, comprising a total of 229 students in Spain from Psychology, Early Childhood Education, Primary Education and Computer Engineering completed the two questionnaires. Results showed that the highest correlation between perceived cooperative activity and self-perceived ability to work in a group was found among computer science students, especially among women, suggesting that the interdisciplinary learning focused on software tool development may be the most effective methodology to improve teamwork and cooperative learning outcomes. Despite these findings concern only to Spanish universities, limiting the generalizability of results, the interdisciplinary methodology seems promising for improving both teaching quality and teamwork skills. The learning methodologies of interdisciplinary projects may therefore need to be implemented within the framework of cooperative and collaborative methodologies.

Keywords Higher Education · Cooperative learning · Collaborative learning · Interdisciplinary learning · Competence-based learning

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Introduction

The European Higher Education Area (EHEA) proposes to improve of the quality of teaching by promoting the student protagonism through active learning (European Ministers of Education, 1999). The new methodologies would aim to create scenarios that allow students to self-regulate their learning and incorporate new strategies during the process (Abramczyk & Jurkowski, 2020; Attle & Baker, 2007; Guerra et al., 2019). Within this framework, cooperative learning has gained considerable traction in higher education as it not only enhances academic performance but also cultivates essential interpersonal skills and problem-solving skills. This approach empowers students to rethink their perspectives and ways of working by collaborating with peers in groups to tackle challenges. It works through five fundamental elements: positive interdependence, promotive interaction, individual responsibility, social skills, and group processing (Johnson & Johnson, 2000, 2014; Loh & Ang, 2020; Nokes-Malach et al., 2015). These elements can be defined as follows: Positive interdependence arises from collective efforts in which the contributions of each group member have a significant impact on outcomes, fostering collaboration and shared success. Promotive face-to-face interaction occurs when members share ideas and problem-solving strategies and collectively manage uncertainties. Individual responsibility emphasizes how an individual's actions affect collective outcomes, reinforcing shared responsibility and positive interdependence. Furthermore, the development of social, leadership, and conflict resolution skills, sometimes requiring guidance from teachers, is crucial to academic growth. Group processing involves effective dynamics within the group, facilitating reflection on acquired knowledge, in line with constructivist theories. In essence, cooperative learning enhances communication between members, deepens engagement with course tasks, promotes autonomy, and cultivates responsibility. As a result, it is considered an effective approach for improving learning outcomes and, consequently, academic performance (Abramczyk & Jurkowski, 2020; Cañabate et al., 2020; Johnson, 2003; Johnson & Johnson, 2014). However, the implementation of cooperative learning in higher education is not without challenges. Large class sizes, group formation, design of the tasks, diverse student needs, teacher´s beliefs about the effectiveness of cooperative learning, and the complexity of assessment can be obstacles (Abramczyk & Jurkowski, 2020; Loh & Ang, 2020).

On the other hand, international organizations and institutions have developed frameworks of competences underlying collaborative skills (Avello & López, 2015; UNESCO, 2011). Collaboration, as a learning strategy, is based on working in small heterogeneous groups that try to achieve common goals and carry out activities together (Dillenbourg, 2009). In these collaborative activities, there is no single right answer and learners must share and reach agreements. The principles of this collaborative learning include consensus through collaboration, voluntary participation, shifting authority from the teacher to the group, working on questions with controversial answers (Bruffee, 1995). The purpose of both cooperative and collaborative learning methods is to provide a framework for peer support. However, the contexts are different and so is the emphasis on activities. While the cooperative model aims to overcome conflicts and learning difficulties due to certain differences among the participants, collaborative learning helps students to deal with their autonomy and the non-foundational knowledge they will be exposed to (González & Díaz, 2005). Furthermore, there are three types of collaboration between different disciplines: multidisciplinary, interdisciplinary and transdisciplinary (Choi & Pak, 2006; Collin, 2009). In multidisciplinary collaboration individuals work independently on different aspects of the same project (Mallon & Bunton, 2005) in parallel or sequentially, but without crossing their knowledge boundaries (Slatin et al., 2004). In the case of interdisciplinary teamwork, individuals collaborate on a common project (Mallon & Bunton, 2005) as is also the case in multidisciplinary partnerships. However, the difference lies in their collective analysis, synthesis and coordination towards its implementation. This approach establishes a higher level of discourse and knowledge integration (Klein, 1990) aligning efforts towards a common goal (Young, 1998) and using a coherent methodology (Pirrie et al., 1998). Transdisciplinary collaboration, on the other hand, involves practitioners from different disciplines coming together to address a common problem, bringing together theories, concepts, and methodologies from each respective field (Slatin et al., 2004).

For the purposes of this study, an interdisciplinary approach has been adopted. In recent years, interdisciplinary initiatives have been developed in a number of areas (Evis, 2022; Goos et al., 2023; Kidron & Kali, 2023; Schijf et al., 2023). These include collaborations between computer science and business students resulting in the creation of tangible software products (Buffardi et al., 2017), with graduate students from social work, civil engineering and computer science (Miller et al., 2019), and with students of civil engineering, applied mathematics and industrial and engineering management (Van den Beemt et al., 2020). These collaborations have facilitated entrepreneurial processes, technological advances for the betterment of society, and the formulation of stochastic models to address transport problems, among other achievements. However, in the field of education and psychopedagogy, it is still an area of research to be explored. Noteworthy studies in the educational field include the works of Urquiza-fuentes and Paredes-Velasco (2016) and Paredes-Velasco et al. (2023) which incorporated real-world projects to promote interaction among students. In these studies, it was possible to carry out realistic experiences through interdisciplinarity with pre-service teachers and future engineers, verifying an improvement in their self-awareness of their group work. They also improved their ability to organize and participate in such work and to accept agreements within the group.

Due to the importance of implementing active learning methods to improve performance, several instruments have been developed and validated to assess their effectiveness. However, in relation to cooperative learning, some of these instruments were based on external observational assessment, such as the Cooperative Learning Observational Schedule (Veenman et al., 2002), or they perhaps omitted the evaluation of some of the dimensions, such as the individual responsibility in the Cooperative Learning Application Scale (CLAS) (Atxurra et al., 2015). Therefore, the Cooperative Learning Questionnaire (CLQ) was used in this study, which was designed and validated for secondary education covering the five dimensions of cooperative learning, (Fernandez-Rio et al., 2017) and subsequently validated in the university context (Delgado-García et al., 2021; Lorente et al., 2021). Regarding team competences, different scales were found, but they were validated in non-Spanish settings, such as the Team Competences Scale (Hebles et al., 2022) or the Teamwork Competence questionnaire (Venrooiji, 2009). Therefore, the Team Competence questionnaire (Paredes-Velasco et al., 2023), which was has been satisfactorily employed in a Spanish context, was used to evaluate the perception of ability to work in team.

Thus, this research consisted of two studies. In the first study the main objective was to evaluate the psychometric properties of instruments used, i.e., the factorial structure and internal consistency of the Cooperative Learning Questionnaire (CLQ) in higher education and the internal consistency of the Team Competence questionnaire. In the second study, the cooperative, collaborative and interdisciplinary learning were analyzed comparing their effects in higher education, involving different bachelor's degrees and teaching professionals. Our main hypothesis was that perceived group cooperative activity and self-perceived ability to work in a group will be positively correlated; second hypothesis was that the interdisciplinary methodology will have a greater effect on teamwork outcomes than cooperative and collaborative learning, and third hypotheses was that the perceived ability to work in a group will be different regarding gender, as prior research stated different attitudes toward team working (Baena-Morales et al., 2020; Feng et al., 2023). Therefore, the specific objectives were to analyze 1) the relationship between perceived group cooperative activity and self-perceived ability to work in a group; 2) differences between educational methodologies and their effect on teamwork and cooperative learning outcomes and 3) differences in outcomes regarding gender.

Methods

Participants

The sample for the study comprised a total of 229 volunteers from University I, Faculty of Psychology, department of Psychobiology and Methodology in Health Sciences: University II, Faculty of Education, department of Mathematics, and University III, Faculty of Computer Science, department of Informatics and Statistics. A total 154 (67.2%) out of 229 students were women, and 75 (32.8%) were men, most in the second year of degree $n=183$ (79.9%), with a range age of 19–22 years (89.5%). Primary education degree involved $n=94$ (41.1%) of students; Psychology $n=58$ (25.3%); Computer Engineering $n=39$ (17.0%) and Early Childhood Education $n=38$ (16.6%). This project was framed within the context of improving teaching quality, thus, no exclusion criteria were stated. Table 1 shows the sample characteristics.

Instruments

The cooperative learning questionnaire (CLQ)

The Cooperative Learning Questionnaire (CLQ) (Fernandez-Rio et al., 2017) was initially designed and validated for secondary education settings, comprising five dimensions: Social Skills (4 items, $\alpha=0.74$), Group Processing (4 items, $\alpha=0.75$), Positive Interdependence (4 items, $\alpha=0.72$), Promoting Interaction (4 items, $\alpha=0.76$), and Individual Responsibility (4 items, $\alpha=0.79$) with a 5-point Likert scale response format (1 = Strongly Disagree, 5 = Strongly Agree). Both the first-order factor analysis in the original sample and the second-order analysis, called Cooperation Factor, presented adequate goodness-on fit indices. However, subsequent studies have shown variations in the dimensions of the CLQ. For instance, Lorente et al. (2021) conducted a validation of the CLQ with second-level Psychology students, identifying four dimensions. The subscales in this study demonstrated good internal consistency, with Cronbach's alpha values ranging from 0.67 to 0.91. Similarly, Delgado-García et al. (2021) validated the CLQ among students from various academic disciplines and educational levels, including undergraduate and postgraduate. This research revealed three dimensions, with subscale internal consistency, as measured by Cronbach's alpha, ranging from 0.70 to 0.86.

Table 1 Descriptives

$n = 229$	n (%)
Age (years)	
18	3 (1.3)
19–20	166 (72.5)
21–22	39 (17.0)
23–24	11 (4.8)
25–30	7 (3.1)
> = 31	3 (1.3)
Sex	
Female	154 (67.2)
Male	75 (32.8)
Bachelor´s degree	
Primary Education	94 (41.1)
Psychology	58 (25.3)
Computer Engineering	39 (17.0)
Early Childhood Education	38 (16.6)
Level of Bachelor´s	
First year	2 (0.9)
Second year	183 (79.9)
Third year	41 (17.9)
Fourth year	3 (1.3)

n = sample, % = percentage

Team competences questionnaire

The "TUNING Educational Structures in Europe" project reworked undertook a comprehensive reconfiguration of university curricula across Europe, delineating learning outcomes through competences. In relation to this new assessment model, Villa & Poblete, (2008) determined three levels and domains to assess teamwork skills: 1) Active participation and collaboration in team tasks, fostering trust, cordiality, and focused engagement in shared work.; 2) Contribution to team consolidation and development by promoting communication, equitable task distribution, a conducive team environment, and cohesion; and 3) Leadership within groups, ensuring member integration and a focus on high-performance orientation. The questionnaire used in this research focuses on the first level (Villa & Poblete, 2008) which allows for the assessment of five dimensions of teamwork: 1) Work: Timely completion of assigned tasks within the established time frame as a member of the group; 2) Participation: Active involvement in team meetings, sharing of information, knowledge, and experiences.; 3) Organization: Collaborative efforts in defining, organizing, and allocating group tasks; 4) Cohesion: Commitment to agreements and shared goals, fostering unity; and 5) Social value of the activity: Consideration of others' perspectives and provision of constructive feedback. For each of these dimensions a Likert scale (1–5) was used. In previous work the instrument was validated with a Cronbach's alpha value of 0.764, which is an acceptable level. Therefore, it can be stated that these indicators are a valid instrument for assessing teamwork skills (Paredes-Velasco et al., 2023).

Procedure

Autonomous University of Barcelona (UAB)

Method_1 Cooperative learning. The response to the Psychology Department's questionnaires came at the end of the Data Analysis course, which was taught by five teachers. The Data Analysis course consists of 6 ECTS credits, representing a total of 150 h for the student. Of this total, 45 h are dedicated to directed training activities based on theoretical lectures and practical classes consisting of problem-solving. A total of 18 h is dedicated to the revision of problems in seminars and personal tutorials with teachers. Various autonomous problem-solving activities are 72 h of the student's time. The remaining hours are dedicated to assessment activities. The assessment structure included two individual evaluations and two group tests. To promote cooperative learning, we designed two tests requiring teams of five members to collaboratively solve statistical problems. To compose heterogeneous group compositions—with varied components, interests, perspectives, and motivations—teams were randomly formed (Johnson et al., 1999). The evaluation of these tests involved an oral presentation of the results by one team member, who was randomly selected by the teacher shortly before the presentation. The assessment criteria were the same for all members and were based on a predefined rubric accessible to both teachers and student teams. The group oral defense, together with the fact that the qualification was the same for all members, would focus on promoting positive interdependence and cooperative skills.

University of Zaragoza

Method_2. Collaborative learning. The response to the questionnaires with the students of the Degree in Early Childhood Education programme came at the end of the Didactics of Mathematics course. This is a subject of 6 ECTS credits, corresponding to 150 h of student work. The distribution of this subject is as follows: 30 h of lessons with the whole group, 24 h of practical work with the divided group, 2 h of small group seminar, 3 h of exams and 91 h of autonomous student work. In the whole-group sessions, we reflected on the importance of the mathematical and didactic contents addressed for the teacher's teaching work and for the student's learning, we presented the concepts that had previously appeared in the split-group classes, and we discussed and corrected the main questionnaires that appeared in them. The divided-group sessions were essentially practical lessons. Stable groups of 5–6 students were formed. Each of these divided groups had a teacher who gave answers to 5 small groups, clarifying doubts without institutionalizing knowledge. The objective of each of these sessions was to solve problem situations, questions and cases by manipulating different didactic materials in order to answer questions posed in the provided script. The small group seminars were carried out with the stable small groups of 5–6 students each. Previously, the pre-service teachers had worked in groups on the development of the script. These seminars took place in the middle and at the end of the four-month period, which made it possible to answer some of the doubts that arose during the seminar.

Rey Juan Carlos University

Method_3. Interdisciplinary Learning. The response to the questionnaires with the students of the Degree in Computer Science came at the end of the Human–Computer Interaction course. This is a subject of 6 ECTS credits, corresponding to 150 h of student work. The distribution of this subject is as follows: 17 h of theoretical contents class with the whole group, 38 h of practical work with the divided group, 12 h of teacher/student personal tutorials, 3 h of exams and 80 h of autonomous student work. An interdisciplinary methodology was used, involving students from two different fields of knowledge. The methodology was developed in two phases. Firstly, the teacher explained the learning task, which was to create a prototype of an educational software tool for teaching mathematical concepts to primary school students. Then, small working groups were formed, consisting of five pre-service teachers at Primary School Degree and three students of Computer Science Degree. Within each small group, two roles were assigned: the role of developer, which was taken by the computer science students, and the role of teacher, which was taken by the pre-service teachers. In the second phase, the small groups worked on the prototypes. Following the classical HCI development methodology for computer systems, this phase was organized in three parts, developed during three sessions: 1) requirements specification, 2) system design and 3) evaluation. During this period, the students attended classes of their respective subjects, Mathematics and its Didactics for the pre-service teachers and Human–Computer Interaction for the computer science students. They also attended three face-to-face sessions to facilitate interdisciplinary collaboration. They used several technology tools such as email, WhatsApp and Teams. Besides, the students used ClipIt to create short videos for sharing prototypes. Computer science students used this platform to present the developed prototypes, while others, the education students, used it to give feedback on the prototypes.

The ClipIt Platform provides support for carrying out video-based learning tasks in a group setting (Llinás et al., 2014). The platform has previously been used in interdisciplinary educational contexts, and it has shown promising results, mainly because it supports interdisciplinary activities (Paredes-Velasco et al., 2023). Students are organized into groups, and the ClipIt platform provides two virtual discussion spaces, one intra-group and the other inter-group. The former is used as a private space for each group where group members share opinions and materials such as documents, videos, etc., and the latter is used to discuss and share information with other different groups. To carry out these actions, these virtual spaces provide students with a forum-like discussion tool and a repository of materials. As mentioned above, ClipIt supports video-based learning. Therefore, the activities are carried out in several steps that focus on the production of a video. In the first step, students engage in a discussion process to create the video script, which is stored in the intra-group virtual space. The second step is the video production. The third and final step is publication of the video with the aim of allowing students from other groups to view it. These steps are organized into different tasks that students carry out progressively. In addition, the tool monitors these tasks so that teachers and students know at what stage of completion they are. For this study, only the first two steps were performed since the focus was on the teamwork approach and not on peer evaluation within the general group that completes the third step. It should be noted, however, that peer evaluation was carried out among members of the same group in the second step. In the experience, students used ClipIt during the second part of the second phase, known as "system design." In addition to supporting the creation and review of video, ClipIt provided students with a list of their group members, activity planning, and links to other sections such as materials provided by the teacher, assignments, discussions, and materials created by the group. Figure 1 shows a screenshot of the ClipIt platform displaying a video replaying of a prototype.

Finally, analyzing the commonalities and differences between the learning approaches is worthwhile. Table 2 shows the main similarities and differences from the perspectives of teaching method and collaboration.

Ethics Committee approval is not required for this project, which was carried out in the context of teaching methods. All students from the three universities participated in the project, but only a sample of volunteers completed the questionnaires. Data were treated in accordance with EU Regulation 2016/679 of the European Parliament and of the Council of 27 April 2016, on personal data, and Organic Law 3/2018 of 5 December, on the guarantee of digital rights. The questionnaires were administered using an online form that maintained the anonymity of the participants and informed them of the purpose of the study, the privacy policy and the right to withdraw from the research without consequences. All participants signed the consent form. Permission to use the CLQ questionnaire was obtained from the author.

Data analysis

A quasi-experimental design only post was carried out. Statistical evaluations were conducted in two separate stages. For calculating descriptive metrics, ANOVA, inter-item and inter-scale relationships, as well as reliability (in terms of internal consistency both with Cronbach's alpha and McDonalds' omega coefficients) the SPSS version 20.0 (IBM, Chicago, IL) was employed. Confirmatory factor analysis (CFA) was carried out using Mplus 8.4. The distribution normality of the variables was gauged using Mardia's coefficient (Mardia, 1974). The Mardia's coefficient for multivariate kurtosis indicated a non-normal distribution across the CLQ items (Mardia coefficient = 156.5169, $c^2 = 6059.515$, gl = 1540, $p < 0.0005$). As a result, we employed the MLM (maximum likelihood with robust standard errors) estimation technique, which is resilient to normality violations (Byrne, 2012). The fit metrics included the Satorra-Bentler S-Bχ2 statistic (Satorra & Bentler, 1994), the CFI (Comparative Fit Index), the RMSEA (Root Mean Square Error Approximation), and the SRMR (Standardized Root Mean Square Residual). According to Hu and Bentler (1999) CFI values of 0.95 or above signify a good fit, although other scholars propose a threshold of 0.90 (Jöreskog et al., 2000). For the RMSEA, values under 0.05 are considered excellent, while those under 0.08 are deemed adequate. Hu and Bentler (1999) recommend SRMR values below 0.08 for a good fit. An invariance analysis was not conducted due to the limited male sample size.

To describe the relationship between perceived group cooperative activity and an individual's self-perceived ability to work within a group, we employed Pearson's correlation coefficients. These correlations were calculated disaggregated by degree and sex, allowing for a more nuanced understanding of potential variations within these subgroups. Finally, Analysis of Variance (ANOVA) was conducted to evaluate the differences between various pedagogical methods and their effects on cooperative learning and teamwork outcomes. The primary objective was to discern whether distinct teaching approaches yielded significant variations in fostering collaboration and team-oriented skills among students. The contrasts between the groups were anticipated a priori, so no correction—like Bonferroni's—made sense.

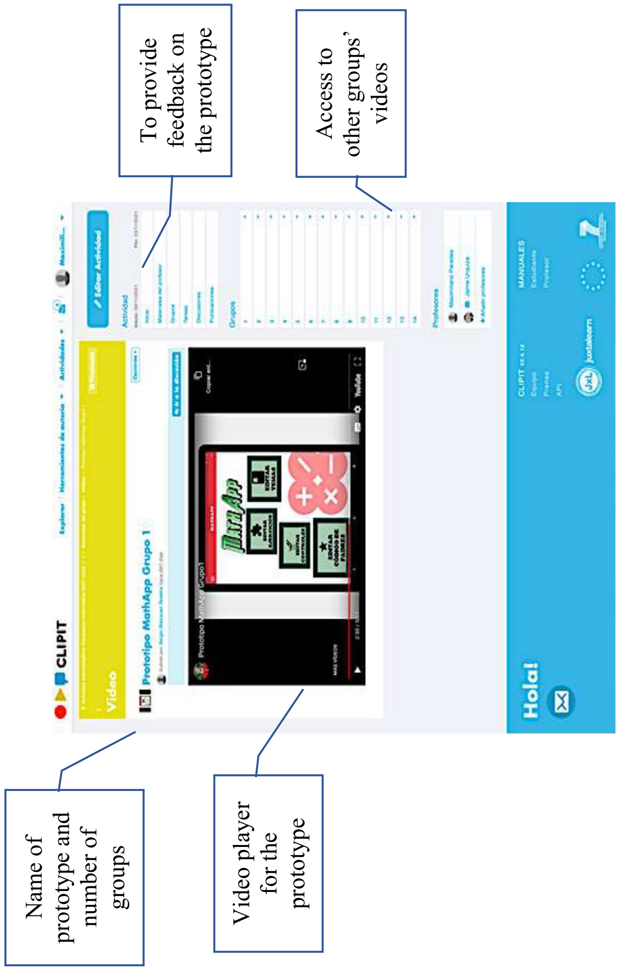

Fig. 1 Screenshot of ClipIt replaying a video created by students

Table 2 Differences and similarities between the methodologies

Methodology features	Method_1 Cooperative learning	Method_2 Collaborative learning	Method_3 Interdisciplinary Learning
Definition	A method of teaching that emphasizes student interdependence and individual accountability in small groups to achieve learning objectives typically through group interaction, discussion, and peer support	A method of teaching in which learners work together in groups to achieve a common goal, usually by completing a task or project that requires teamwork, communication and problem-solving skills	A method of teaching that enables teachers and learners to make connections between learning by exploring relevant links across the curriculum. It provides opportunities to deepen learning, for example by answering big questions, exploring an issue, solving problems or completing a final project
Learning approach	Group work	Group work	Group work
Group formation in this project	Randomly	Randomly	Role assignment
Teaching method for theoretical content	Lecture & use cases resolving	Lecture & use cases resolving	Lecture & use cases resolving
Teaching method for practical content	Hypothetical use cases solving	Hypothetical use cases solving	Real-world problem-solving
Individual/group work ratio	High	Low	Low
Use of technological tools for communication	Low	Low	Intensive
Group Assessment	Oral defense	Oral defense	Oral defense

Results

Study 1

Factor analysis of CLQ

Figure 2 shows the four-factor model, where the Social Skills and Processing Group dimensions converge in only one (hs_pg). The model shows adequate fit indexes: Root Mean Square Error Approximation (RMSEA = 0.060, 95CI% 0.049 – 0.070);

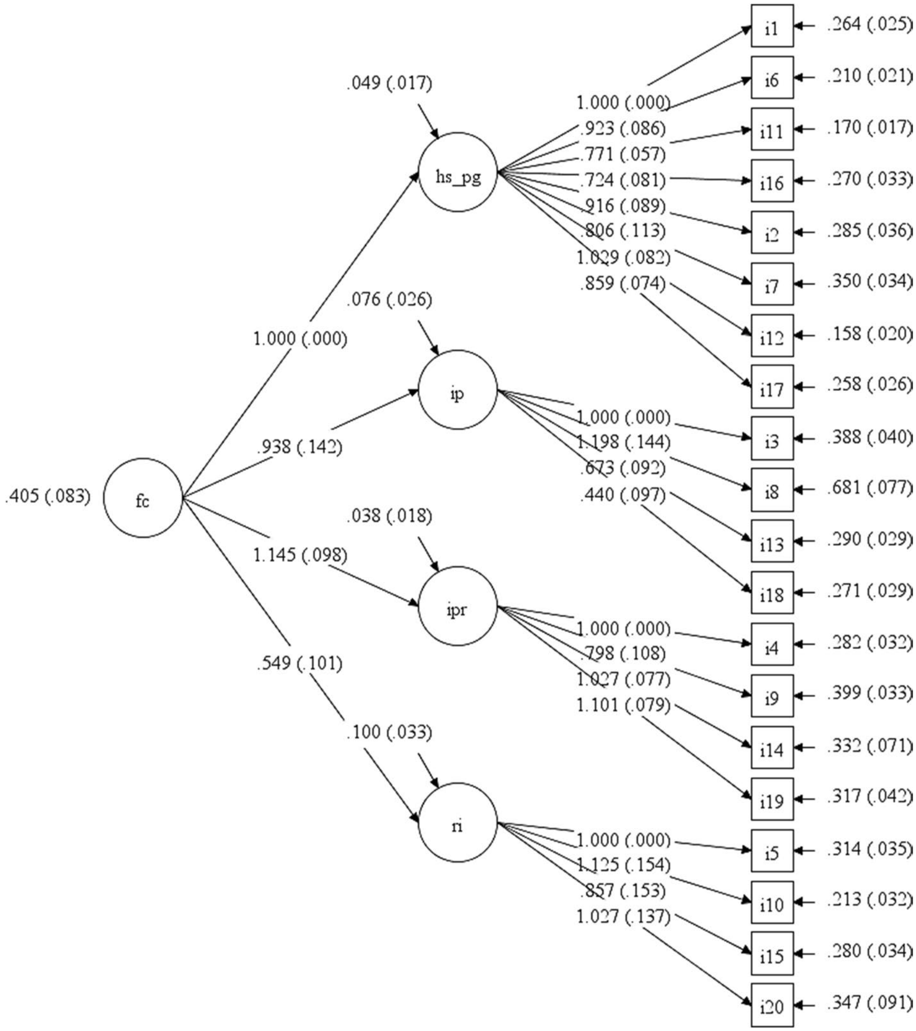

Fig. 2 Confirmatory Factor Analysis (CFA). Cooperative Learning Questionnaire. Chi-Square Test of Model Fit = 300.708 (df 166), $p = < 0.001$; Root Mean Square Error Of Approximation (RMSEA) = 0.060 (95CI% 0.049 – 0.070); Standardized Root Mean Square Residual (SRMR) = 0.057; Comparative Fit Index (CFI) = 0.920; Tucker-Lewis index (TLI) = 0.908; Bayesian information criteria (BIC) = 8826.5. hs_pg = Social skills + Processing group dimension; ip = Positive interdependence; ipr = Promotive interaction; ri = Individual accountability

Standardized Root Mean Square Residual (SRMR = 0.057); Satorra-Bentler (Satorra & Bentler, 1994) S-Bχ2 (166) = 300.708, $p < 0.001$. In our study the model yielded in three dimensions due to the occurrence of a Heywood (1931) case where the model estimates variances of negative correlations or correlations between latent variables greater than one, neither of which is possible. This phenomenon usually occurs when there is a high correlation—close to redundancy—between the observed variables. Examination of the correlation matrix between scales suggests that this may be due to the very high correlation between the social skills and group processing scales, $r = 0.86$.

Reliability internal consistency

Table 3 shows scoring and internal consistency of the CLQ and Team competences questionnaires, with aggregated data. The CLQ total Cronbach´s alpha was α = 0.942, and subscales ranged from α = 0.709 to α = 0.917. The CLQ total Mc Donald's omega was ω = 0.944, and subscales ranged from ω = 0.716 to ω = 0.918, showing a good internal consistency. The CLQ total mean score was > 4. Considering that only the 17% of respondents achieved the highest possible total score, results suggested good cooperative learning. In the same line, the Team Competences also showed good internal consistency, as Cronbach's alpha was α = 0.815 and Mc Donald's omega was ω = 0.816.

Study 2

Hypothesis 1. Relation between perceived cooperative activity and self-perceived ability to work in group

Table 4 shows the correlations between the CAC and Team Competences questionnaires, disaggregated by degree and gender, to assess the relationship between perceived group cooperative activity and self-perceived ability to work in a group, as well as the differences in the relationship between different educational contexts. The computer

Table 3 Scoring and internal consistency

n = 229	Mean (SD)	α	ω
Cooperative Learning Questionnaire		0.942	0.944
Social Skills + Group Processing	4.4 (0.6)	0.917	0.918
Positive Interdependence	4.3 (0.6)	0.709	0.716
Promotive Interaction	4.2 (0.5)	0.861	0.867
Individual Responsibility	4.4 (0.6)	0.752	0.750
Team Competences		0.815	0.816
Timely completion of assigned tasks	4.3 (0.7)		
Active involvement in team meetings	3.8 (0.8)		
Definition, organization, distribution tasks	4.0 (0.9)		
Commitment to agreement and shared goals	4.0 (0.7)		
Consideration of others' perspectives	4.1 (0.8)		

SD = Standard deviation; α = Cronbach´s alpha; ω = Omega coefficient

Table 4 Correlations between variables. By Bachelor´s degree and sex

Psychology	Cooperative Learning Questionnaire							
Team Competences	hs_pg		Positive Interdependence		Promotive Interaction		Individual Responsibility	
	W	M	W	M	W	M	W	M
Timely completion of assigned tasks	-.293	-.258	-.132	-.392	-.134	.106	-.155	.214
Active involvement in team meetings	-.036	-.0.62	-.109	-.141	.045	.142	.148	-.244
Definition, organization, distribution tasks	-.221	.512	.044	.139	-.113	.513	.002	.183
Commitment to agreement and shared goals	.062	-.097	.013	-.720**	.009	-.285	-.006	.439
Consideration of others' perspectives	-.016	-.017	.206	.285	-.016	-.239	.154	-.106
Early Childhood Education	Cooperative Learning Questionnaire							
Team Competences (All participants were women)	hs_pg		Positive Interdependence		Promotive Interaction		Individual Responsibility	
Timely completion of assigned tasks	-.057		-.224		-.113		-.042	
Active involvement in team meetings	.337*		.367*		.465**		.409*	
Definition, organization, distribution tasks	.192		.239		.275		.481**	
Commitment to agreement and shared goals	.254		.257		.228		.321*	
Consideration of others' perspectives	.387*		.302		.210		.238	
Primary Education	Cooperative Learning Questionnaire							
Team Competences	hs_pg		Positive Interdependence		Promotive Interaction		Individual Responsibility	
	W	M	W	M	W	M	W	M
Timely completion of assigned tasks	.454**	.305	.374**	.239	.423**	.369	.202	.224
Active involvement in team meetings	.502**	.405*	.266*	.523**	.454**	.435*	.211	.247
Definition, organization, distribution tasks	.143	.331	.084	.147	.103	.334	.026	.087
Commitment to agreement and shared goals	.438**	.135	.272*	.154	.396**	.118	.114	.020
Consideration of others' perspectives	.339**	.532**	.246*	.452*	.311*	.536**	.204	.245

Table 4 (continued)

Psychology	Cooperative Learning Questionnaire							
Team Competences	hs_pg		Positive Interdependence		Promotive Interaction		Individual Responsibility	
Computer Engineering	Cooperative Learning Questionnaire							
Team Competences	hs_pg		Positive Interdependence		Promotive Interaction		Individual Responsibility	
	W	M	W	M	W	M	W	M
Timely completion of assigned tasks	.958*	.695**	.459	.530**	.826	.510**	.875	.575**
Active involvement in team meetings	.793	.574**	.258	.434*	.631	.556**	.688	.513**
Definition, organization, distribution tasks	.813	.419*	.983**	.264	.952*	.160	.919*	.439**
Commitment to agreement and shared goals	.165	.448**	.513	.289	.326	.416*	.280	.386*
Consideration of others' perspectives	.867	.605**	.674	.620**	.857	.517**	.869	.546**

Significant values are in bold

W = Women; *M* = Men; hs_pg = Social skills + Group processing dimension; p value: $p < 0.001$ **; $p < 0.05$*

science degree showed the highest correlation between perceived cooperative activity and self-perceived ability to work in a group.

Hypotheses 2. Interdisciplinary methodology comparing with cooperative and collaborative learning

Table 5 shows the results of the analysis of variance (ANOVA) carried out to assess the differences between the pedagogical methods and their impact on the cooperative learning and teamwork outcomes. The model for cooperative learning shows adequate goodness-on fit indices with R squared of 0.26 and R squared adjusted of 0.25, whereas the model for team competences shows lower R squared, 0.136, and R squared adjusted of 0.121. The effect of different methods on cooperative learning and teamwork is statistically significant ($p < 0.001$). Multiple comparisons show that interdisciplinary learning leads to the best improvement in cooperative learning and teamwork, with higher effect in teamwork competences.

Hypotheses 3. Differences regarding gender

It is noted that there were strong correlations in women computer engineering students, ranging from r = 0.793 to r = 0.958 (Dancey & Reidy, 2007). In addition, it is worth noting the strong negative correlation in psychology students, specifically men, between "Commitment to agreement and shared goals" and "Positive interdependence". Concerning the differences of methods and their impact on teamwork outcomes, gender seems to be a statistically significant covariant, but the interaction with method was negative, leading to the inference that the two variables do not interact with each other.

Discussion

To the best of our knowledge, this is the first study to compare these three active learning methodologies in higher education assessing their impact in different academic disciplines considering gender differences. In addition, this research provides more evidence of the structure of the CLQ, and the internal consistency of the Teams Competences questionnaire, thus supporting their use in the higher education to evaluate the effectiveness of cooperative, collaborative and interdisciplinary learning methods.

CLQ and team competences psychometric properties

Regarding the structure of the CLQ, the original five factors could not be confirmed due to the high correlation between the group processing and social skills dimensions. Our investigation revealed a model fit with four dimensions, potentially influenced by various factors. Firstly, the variation may be attributed to the significant age range variation in our sample, potentially affecting personal and identity maturation, differing from the original validation sample. Secondly, the challenge in differentiating between these two dimensions could stem from the inherent complexity of the 'Group Processing' factor, which

Table 5 ANOVA. Comparison of methodologies

Bachelor					
	Methodology			***n* (229)**	**%**
Psychology	Method_1			58	25.3
	Men			14	6.1
	Women			44	19.2
Early Childhood Education	Method_2			38	16.6
	Men			0	0
	Women			38	16.6
Computer Engineering + Primary Education	Method_3			133	58.0
	Men			61	26.6
	Women			72	31.4
ANOVA					
Cooperative Learning Questionnaire*	**Coef**	**df**	**QM**	**F**	***p***
Model	18.99	4	4.75	19.781	**< 0.001**
Constant	2530.87	1	2530.87	10,544.81	**< 0.001**
Sex	2.90	1	2.90	12.100	**0.001**
Method	16.60	2	8.30	34.582	**< 0.001**
Sex # Method	0.30	1	0.30	1.268	0.261
Error	53.76	224	0.24		
Total	4457.05	229			
Team Competences**					
Model	274.12	4	68.53	8.83	**< 0.001**
Constant	55,305.72	1	55,305.72	7126.70	**< 0.001**
Sex	55.50	1	55.50	7.151	**0.008**
Method	189.216	2	94.61	12.191	**< 0.001**
Sex # Method	0.341	1	0.34	0.044	0.834
Error	1738.32	224	7.76		
Total	96,637.00	229			
Multiple comparisons					
Cooperative Learning Questionnaire	**Contrast**		**Std Err**	**CI 95%**	***p***
Method_1 vs. Method_3	0.71		0.09	0.54 – 0.88	**< 0.001**
Method_2 vs. Method_3	0.48		0.11	0.26 – 0,69	**< 0.001**
Team Competences					
Method_1 vs. Method_3	2.43		0.49	1.45 – 3.40	**< 0.001**
Method_2 vs. Method_3	1.45		0.62	0.24 – 2.67	**0.019**

Coef. = Coeficient; df = degree of freedom; *QM* = Quadratic Mean; *CI* = Confidence Interval 95%; F = F Snedecor; *p* = *p* value; Std Err = Standard Error. Method_1 = Cooperative_Learning; Method_2 = Collaborative learning; Method_3 = Interdisciplinary learning *ANOVA Model of Cooperative Learning Questionnaire = R squared 0.261; R squared adjusted 0.248; **ANOVA Model of Team Competences = R squared 0.136; R squared adjusted 0.121

encompasses both inter-group dynamics and individual social skills. Similarly, Delgado-García et al. (2021) identified a distinct factor model while analysing the CLQ with a sample of 500 students, encompassing both undergraduates and postgraduates. Their findings suggested a three-factor model, specifically ’Group Learning’, ’Group Obligations’, and ’Group Follow-up Techniques’. Discrepancies between these studies could be linked to differences in sample size and the educational level of the students. Notably, the inclusion of master’s students in Delgado-Garcia et al.’s (2021) sample, typically exhibiting greater maturity and enhanced training in learning methodologies during their undergraduate studies, could account for these differences. Given these findings, further research is necessary to establish a more stable and uniform model for higher education, ideally using more homogeneous samples (e.g., exclusively undergraduates or postgraduates). It is worth noting that the original version has recently been adapted into English, making it suitable for use in both secondary and higher education contexts (Fernandez-Rio et al., 2022).

Relationship between cooperative activity and teamwork perception

In examining the relationship between perceived group cooperation and self-perceived ability, high correlations were found in the engineering discipline in particular, partially confirming our first hypothesis. Particularly strongest correlations were observed in the variable *Definition, organisation, distribution group’s task*—associated with the organization of activities- specifically among engineering students. This outcome can be attributed to the methodology utilized in their classes, notably interdisciplinary learning. This specific variable was also where Paredes-Velasco et al. (2023) identified significant differences before and after implementing the same interdisciplinary methodology. Within the subgroup of computer science students, these strong correlations only occur among women which is attributed to the fact that, as Tamayo et al. (2017) noted, they are the ones who are more demanding and critical and consider teamwork to be essential. Noteworthy was the strong negative correlation between the variables *Positive Interdependence* and *Commitment to agreement sharing goals* observed solely among men psychology students who followed cooperative methodology. This fact contrasts with existing literature highlighting the expected positive relationship between these variables (Abramczyk & Jurkowski, 2020; Cañabate et al., 2020; Loh & Ang, 2020), but in line of prior research that establish gender differences in cooperative learning effectiveness, as women have more positive attitudes toward cooperation and social interdependence, and men seem to be more autonomous, having a separate perception of self (Baena-Morales et al., 2020; Gupta et al., 2014). In light of these findings, success in improving performance at university may be related to the composition of teams, which should be heterogeneous in terms of interests and gender balanced to facilitate collaboration regardless of the method.

Impact of methodologies on cooperation and teamwork

Differences between different educational contexts may be due to student´s particular regulatory and processing learning strategies, but also to students’ socio-emotional competences. As suggested by Demulder et al. (2023) it´s plausible to identify distinct student profiles, including ’passive explorers’, who exhibit minimal engagement in orientation, self-regulation, and deep exploration; ’moderately active explorers’ engaging moderately in choice-related activities and broad exploration; and ’highly active explorers’ who significantly involve themselves in orientation and exploration activities compared to other profiles. These profiles potentially influence both individual and collective decision-making processes. Furthermore, socio-emotional competences that include effective communication, conflict management, empathy, assertiveness, and consensus building, among others, serve as predictive factors for enhanced academic performance. Their impact extends beyond educational spheres, significantly influencing social interactions as well (Puertas-Molero et al., 2020). In this sense, Castejón et al. (2008) noted differences in the profile of socio-competences and personality traits in students from different disciplinary areas. Specifically, research findings revealed that students in Health Sciences and Education consistently scored lower across almost all variables, except for 'stress management', whereas students in Technologies exhibited lower scores in 'emotional attention' but showcased higher aptitude in 'interpersonal relations' and 'adaptability'. The authors postulated that reduced emphasis on 'emotional attention' among Technology students could be advantageous, as excessive focus on emotions might potentially impede performance. Conversely, heightened interpersonal skills, pivotal in organizing and structuring work, stand as crucial competencies for engineers leading work teams. Moreover, disparities between pedagogical methods and their impact on teamwork outcomes were evident, with interdisciplinary methodologies yielding superior results, confirming our second hypothesis. These differences may partly stem from the challenges associated with effectively implementing cooperative and collaborative learning methods, as previously noted. Obstacles such as large class sizes, complexities in group formation, task design, diverse student needs, instructors' beliefs regarding the efficacy of cooperative learning, and the intricacies of assessment practices have been highlighted as potential barriers (Abramczyk & Jurkowski, 2020; Loh & Ang, 2020).

The results regarding efficacy of interdisciplinary methodology align with parallel findings in previous studies. Vogler et al. (2018) identified teamwork, oral communication, and critical thinking as the top three soft skills most pertinent to students engaged in interdisciplinary projects. Similarly, Hart (2019) and other studies have highlighted the significant development of teamwork skills within interdisciplinary work environments. The experience conducted int this study provides evidence that the interdisciplinary approach enhances students' perception of teamwork skills and cooperative work in contrast to cooperative and collaborative learning methodologies. Several factors could have contributed to this improved perception of teamwork and cooperative skills among students. Firstly, the interdisciplinary approach was implemented through Human–Computer Interaction (HCI) and User-Centered Design (UCD) methods, in which social interaction plays a crucial role. These methods use techniques to capture the opinions of users of computer systems. Computer science students were taught how to use and apply these techniques in collaboration with education students. As a result, the students benefited from methods such as interviews, surveys, focus groups, brainstorming, etc., which enriched their perception of teamwork, especially in an interdisciplinary environment where different perspectives from different fields of knowledge emerge (Paredes-Velasco et al., 2023). Secondly, real projects that promoted the interdisciplinary approach could have a significant impact. Interdisciplinary projects inherently promote the acquisition of essential soft skills (Vogler et al., 2018). Furthermore, pedagogical strategies that focus on simulating real-world situations are effective in fostering interdisciplinary teamwork (Klipfel et al., 2014). Simulated environments based on Problem-Based Learning (PBL), in which students collaborate in different roles, facilitate the development of teamwork skills (Sancho-Thomas et al., 2009). Furthermore, the use of real-world problem-solving approaches within collaborative learning environments promotes active student engagement and enables the integration of different perspectives within the team, facilitating various soft skills, such as teamwork (Huang, 2010). In the interdisciplinary approach used in this experience, computer science students had to develop an educational computer tool in a realistic context, with future teachers taking the role of users and technology students taking the role of developers.

Technology is another factor to consider in interdisciplinary approaches (Gutiérrez et al., 2022), which could have contributed to perception of cooperative and teamwork. While the use of technology was limited in cooperative and collaborative approaches, it was used extensively and played a fundamental role in interdisciplinary learning. ClipIt served as the technological platform for the development of the interdisciplinary experience. This online platform supports social learning, encourages self-driven reflection among students, and places a strong emphasis on social interaction and collaboration (Llinás et al., 2014). Therefore, this technological tool has the potential to enhance students' perceptions of cooperation and teamwork activities. Other interactive technology-assisted tools may be used with the same objective, such as decision-guided chatbots, which are commonly used in interdisciplinary learning across different academic disciplines and cultural backgrounds (Iku-Silan et al., 2023; Jeon et al., 2023). In particular, Iku-Silan and colleagues applied multidisciplinary learning with indigenous children from the Tayal culture in northern Taiwan. A decision-guided chatbot system was developed to learn about the use and cultural aspects of plants and the environment. The system architecture consisted of three main modules: 1) the cultural characteristics module, 2) the plant usage and type module, and 3) the interactive learning module. The results of this work provide evidence that multidisciplinary learning can be generalized across cultures and disciplines, and that it has a positive impact on learning outcomes, motivation and group work effectiveness when combined with guided interactive systems.

Finally, socio-cultural aspects might have influenced the collaboration between students in this study. Socio-cultural aspects of a society have strong influences on students' motivation to develop careers in engineering in general (Balakrishnan & Low, 2016). Spanish universities mainly organize engineering education courses in four academic years, with theoretical contents and lectures predominating in the first years, while practical contents and active learning become more prominent in the last two years (BOE, 2023). The authors consider that if the study had been conducted in a different cultural setting, the collaboration between students would have been different. For instance, in an educational setting where courses incorporate active learning from the first academic year, students may experience a heightened level of interaction with their peers, resulting in an improvement of teamwork skill. Social factors such as interaction with peers and teachers, as well as the use of social media, positively impact active collaborative learning and student involvement (Qureshi et al., 2023).

Conclusions

Effective teamwork necessitates a specific set of skills and social competencies, encompassing adaptability, leadership, effective communication, conflict management, and empathy. The effective management of teamwork is becoming crucial for organisations, either in technologies, such as computer engineering, where institutions focus on the dynamics of team communication patterns to promote team effectiveness, or in health sciences, which focus on the concept of team-centered leadership, among others (Kozlowski, 2018). In this line, higher education should rethink the conventional teaching in order to promote social competences and skills that allow students to adapt their curricula to the current professional demands. Therefore, student-centered learning methodologies should be disseminated, as interdisciplinary learning methodologies are the most promising to develop teamwork competences. The learning methods of interdisciplinary projects may therefore need to be implemented within the framework of cooperative and collaborative methodologies, together with specific teacher and student training and cooperation between higher education institutions.

Practical implications

The effective implementation of active learning strategies in the future depends on several key factors. First, teachers need adequate resources, including materials, time and specialised training, to encourage and enhance student engagement and to provide constructive feedback. Secondly, students themselves need specific training in collaborative working methods, equipped with tools that facilitate social interaction and conflict resolution within relationships. Finally, institutions and school administrators have a crucial role to play in supporting teachers by providing sufficient time and minimising obstacles and challenges (Kaendler et al., 2015; Loh & Ang, 2020). Future research should explore the teacher's perspective in more depth, particularly in relation to barriers to implementation. In addition, assessing students' perspectives on active learning methods and their correlation with professional integration is an area ripe for exploration.

Limitations and strengths

A number of limitations need to be considered. Firstly, the relatively small sample size, coupled with gender imbalances in certain degree courses, makes it difficult to analyze measurement invariance and limits the generalizability of the results. In addition, potential bias could arise from the choice of degree programmes to implement each methodology. Secondly, the lack of assessment of specific variables of personality traits and socio-emotional competencies makes it difficult to determine their impact on the effectiveness of the methods on team outcomes. In addition, the evaluation of the study included different teachers from three universities, introducing heterogeneity that could have influenced the results, but the interdisciplinary methodology seems promising for improving both teaching quality and teamwork skills. These findings concern only to Spanish universities, but the study has notable strengths. It evaluated different active learning methodologies, in line with the student-centred approach advocated by the European Higher Education Area (EHEA). Furthermore, the study involved different disciplines, each with unique academic profiles and social skills, which enriched both the process and the results. Finally, this study supports the use of guided interactive systems to improve the academic performance within the context of interdisciplinary methodology.

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Data availability Data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Declaration of generative AI and AI-assisted technologies in the writing process During the preparation of this work the author(s) used [CHAT Openai / GPT-3.5] in order to improve the writing. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Conflict of interest No conflict of interest.

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